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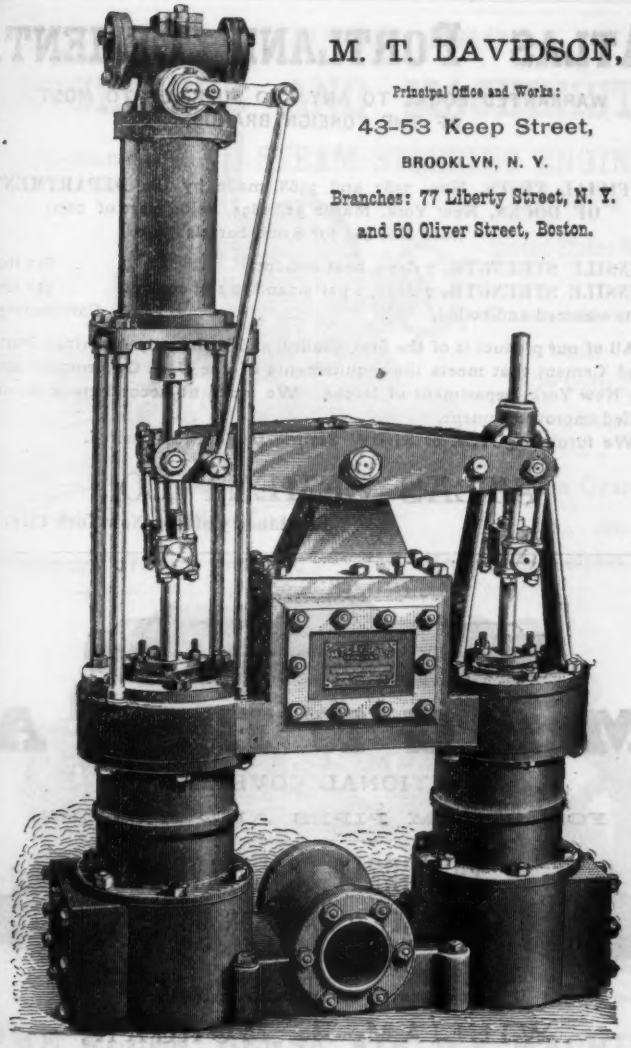

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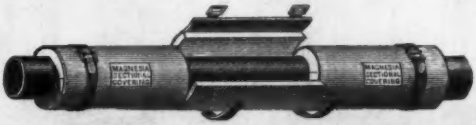

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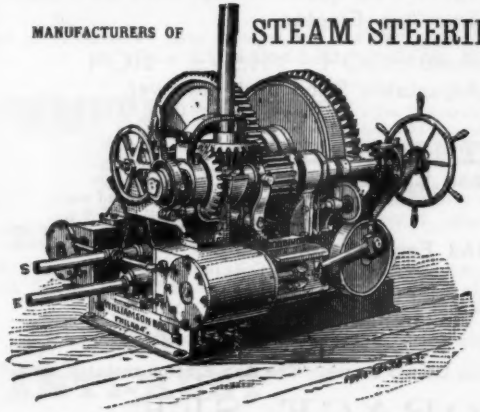

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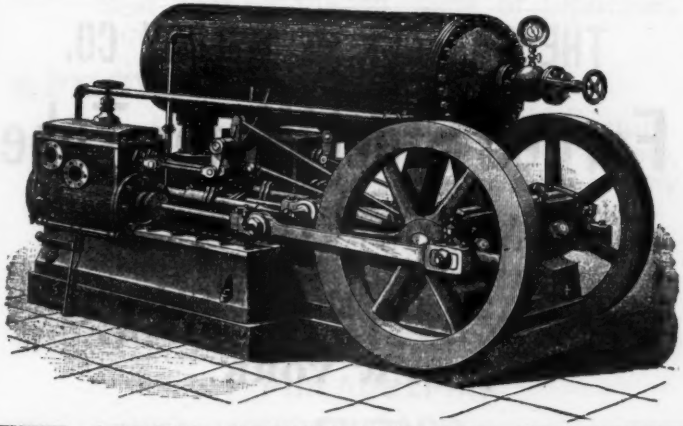

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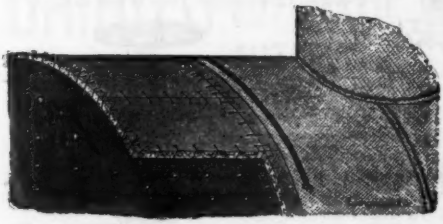

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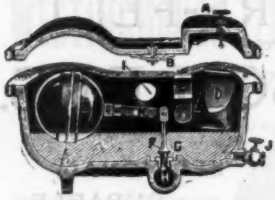

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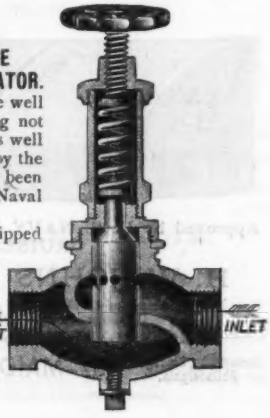

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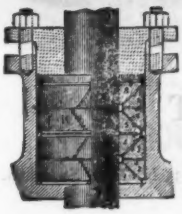

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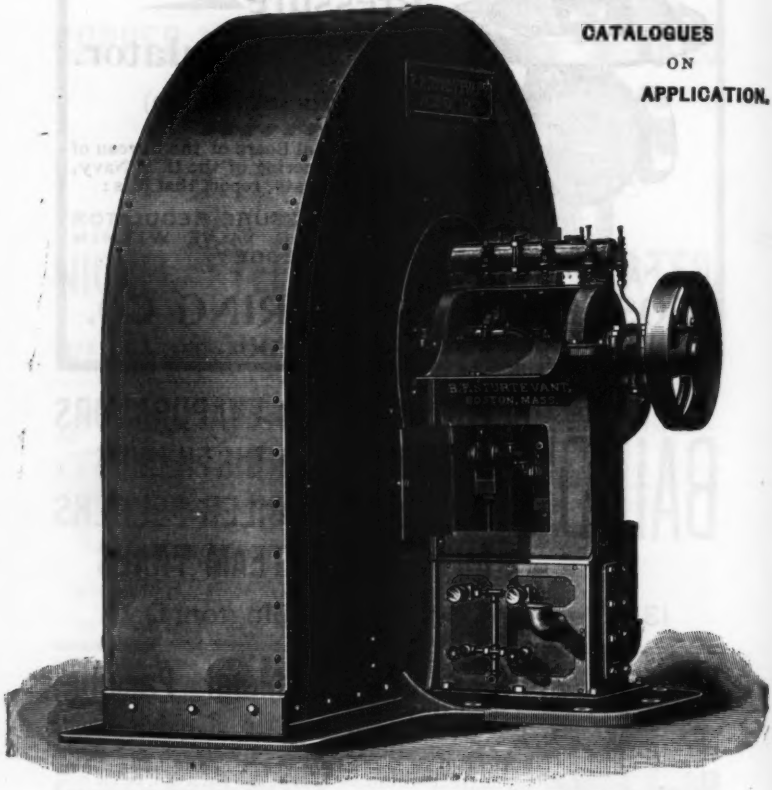

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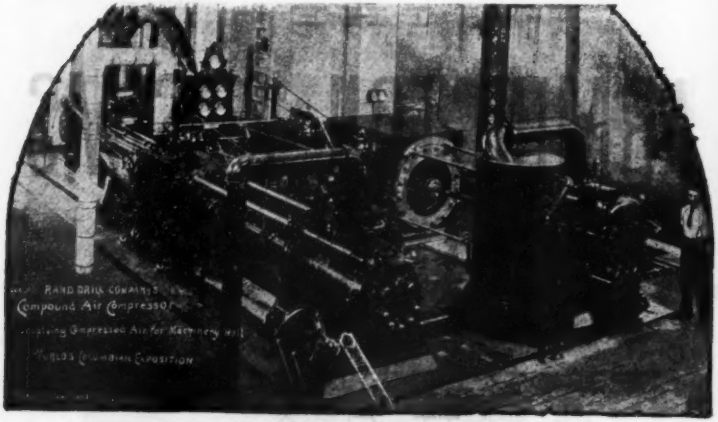

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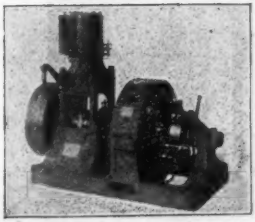

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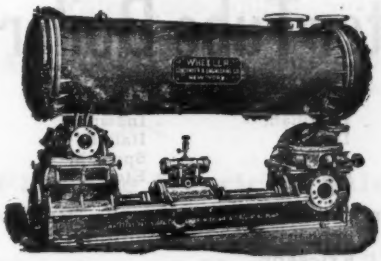

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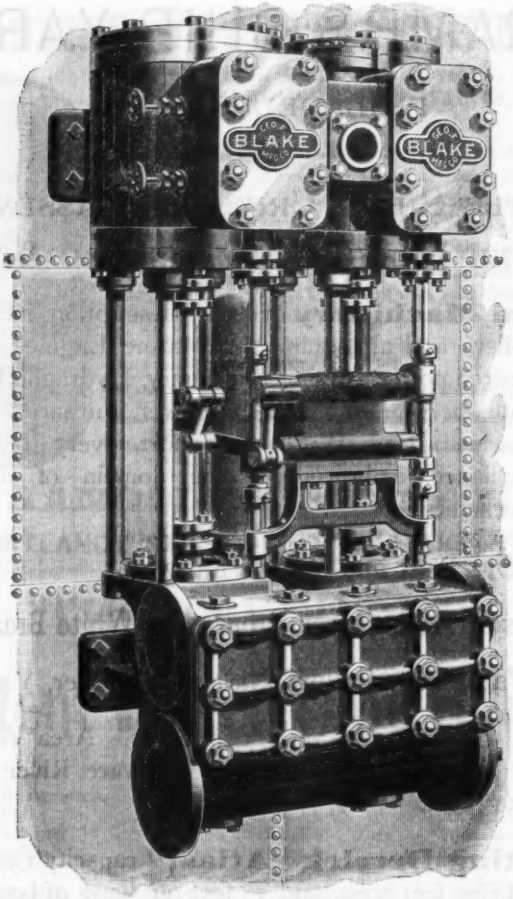

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OF THE

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VOL. VIII. AUGUST, 1896. No. 3.

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CONTRACT TRIAL OF THE UNITED STATES COAST-LINE BATTLE SHIP *OREGON.*

BY LEO D. MORGAN, ESQR., MEMBER.

The *Oregon*, a sister ship to the *Indiana* and *Massachusetts*, is a twin screw, armored, coast-line battle ship of 10,250 tons displacement at a mean draught of 24 feet, and was built by the Union Iron Works of San Francisco, Cal. The contract was signed on November 19, 1890, and the vessel was to be completed in three years. The contract price for machinery and hull, exclusive of armor, was $3,180,000. Before work was commenced, however, it was decided to increase the length of the ship from 344 to 348 feet at an additional cost of $42,810, making the contract price $3,222,810. The general plans and specifications were furnished by the Navy Department, the developments were made by the contractors and approved by the proper bureaus.

The first keel plate was laid November 19, 1891; the first frame was raised December 19, 1891; the first rivet was driven January 14, 1892; and the launch took place on October 26, 1893. On May 14, 1896, the *Oregon* was given her official speed trial

in Santa Barbara Channel. Her average speed for the four hours was 16.791 knots, thus beating the records of the *Indiana* and *Massachusetts* by 1.254 and .5831 knots, respectively. The guaranteed speed was 15 knots, to be maintained for four consecutive hours under forced draft with an air pressure not to exceed one inch, at a mean draught of 24 feet. It was further agreed that for every quarter knot above the guaranteed speed, the contractors were to receive a bonus of $25,000, and for every quarter knot less than the guaranteed speed, the sum of $25,000 was to be deducted from the contract price.

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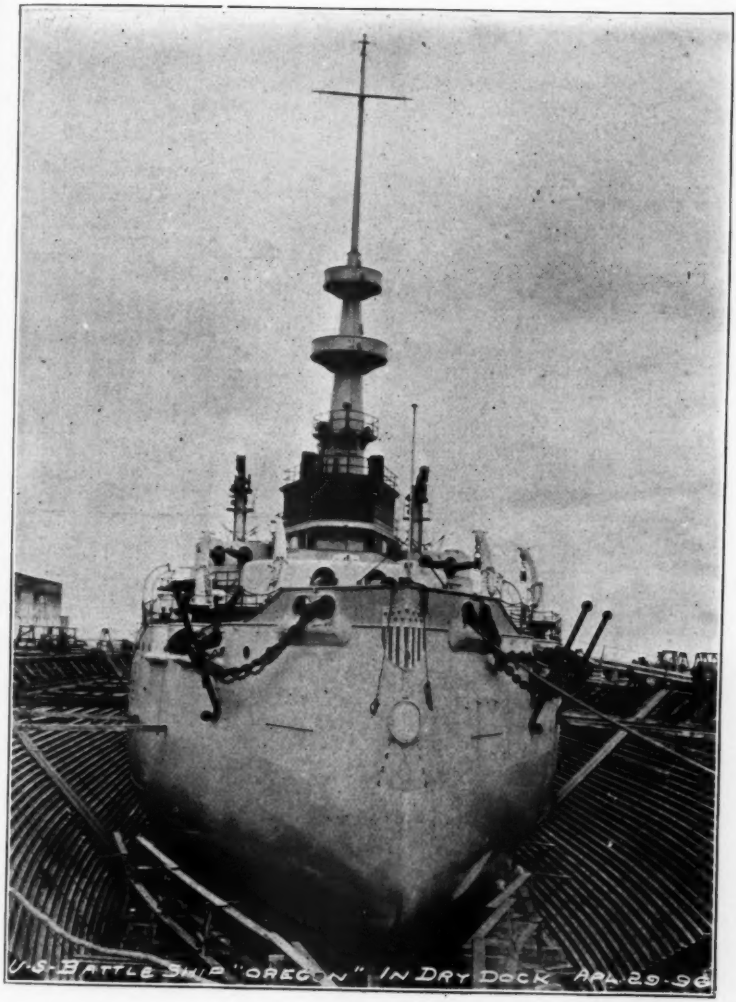
Hold.—The forward hold is taken up by trimming tanks, chain lockers, 6 and 8-inch shell rooms and magazines, and 6 and 1-pounder ammunition rooms. Amidships are the boilers, engines, coal bunkers, and hydraulic pumps for the 13-inch turrets. In the after hold are trimming tanks, 6 and 8-inch shell rooms and magazines, rooms for fixed ammunition and engineer's stores.

After Platform.—On this platform there are 13-inch magazines and shell rooms, 13-inch handling room, torpedo machinery, store rooms and steering gear.


U.S. BATTLE SHIP "OREGON" IN DRY DOCK APL 29-98

Forward Platform.—On this platform there are 13-inch magazines and shell rooms, 13-inch handling rooms, torpedo heads, ordnance stores, electric stores and fixed ammunition.

Orlop Deck.—On the orlop deck there are the reserve coal bunkers, main ammunition passing rooms, ammunition passages, auxiliary magazine and 8-inch turret machinery.

Berth Deck.—On the berth deck are the living quarters for officers and crew, coal bunkers, refrigerating plant, auxiliary boilers, work shops and torpedo rooms.

Coal Bunkers.—The coal bunkers are 28 in number with a total capacity of 1,594.46 tons at the rate of 42 cubic feet per ton. Their distribution is as follows: berth deck, 8, capacity, 229.94 tons; orlop deck, 4, (reserve) capacity, 118.60 tons; hold, 16, capacity, 1,245.92 tons. Between decks, chutes and trunks for filling the bunkers are fitted. The trunks, where they pass through the bunkers on the berth deck, have shunt doors at the top and vertical doors at the bottom, to enable coal to be passed from these bunkers into the trunks and into the bunkers below through the orlop deck.

Ash Chutes.—The ash chutes are four in number, two on each side, semi-oval in shape and fitted to the outside of the vessel. Their upper ends extend above the main deck and terminate in suitable hoppers built into the inside of the vessel. Trolley-ways lead from the several ash hoists to the chutes.

DRAINAGE SYSTEM.

Main Drain.—The main drain is on the starboard side and is in the double bottom. It is connected to the inner bottom by six 6-inch main drain valves located in fire rooms Nos. 3, 4, 7 and 8 and in the engine rooms. The 14-inch main begins about two feet forward of the bulkhead in fire rooms 3 and 4, and extends to about the center of engine space. 11-inch branches connect the main drain valves to the main and also to the main drain wells in engine rooms. From the forward end of main drain valve in No. 3 fire room, an 8-inch branch extends forward to midway between frames Nos. 21 and 20, where it connects with

a 6-inch cross pipe, the forward terminals of the 6-inch drain from the protective deck. From the after side of the main drain wells, on the port side, an 8-inch branch extends aft to a 6-inch cross pipe, passing between frames 64 and 65, the after terminals of the 6-inch drains from the protective deck. In each engine room there is a 12-inch suction from the main drain wells to the main circulators. There is also a 7-inch drain from the main wells to the engine room manifolds. The four main drain valves in fire rooms are worked from the berth deck, and those in the engine room, from the top platform. The side compartments drain into the midship compartments through $5\frac{1}{2}$ by $5\frac{1}{2}$-inch sluice gates on the fourth longitudinals, operated from the upper wing passage. All compartments on the protective deck are drained through separate drain valves and branches leading into the 6-inch protective deck drains, located underneath the deck and connecting with the main drainage system as before described. All compartments on the orlop deck are drained through separate drain valves and pipes discharging on the inner bottom. On the platform deck, all compartments forward and aft of frames Nos. 22 and 71 drain into the bilge, and all compartments between these frames drain on the inner bottom. There are no drains on the berth deck within the casemate armor; forward and aft of this the drains lead to scuppers with gate valves, worked from berth deck, and all bath tubs, lavatories, pantries, etc., drain overboard. The lower bunkers drain through flap valves on the inner bottom.

Secondary Drain.—The secondary drain is 6 inches in diameter, and extends throughout the machinery and boiler compartments, connecting to the manifold in fire room No. 2, and also, by a cross pipe, to the manifold in fire room No. 1. It extends aft on the port side over the inner bottom almost to frame No. 52, with branches leading to the bilge wells at after ends of main boilers, and thence to the auxiliary feed pumps. Near frame No. 51, the secondary drain passes down into the double bottom and continues aft to the forward bulkhead of engine compartments, connecting through the bulkhead above fire room floor with the manifold in port engine room. On the fire room side

of this bulkhead, a short branch passes inboard, parallel to the bulkhead, and passing through, continues aft to within a few inches of the center of the after crank pit drain, crosses over to the starboard side until it reaches a point about midway between the main injection and discharge pipes, and then aft to the manifold on after bulkhead in starboard engine room. On the starboard side, there is a 6-inch branch connecting the secondary drain with the main drain well. At the end of this branch, within the well, there is a 6-inch angle valve with pipe leading nearly to bottom of well. The valve is operated by means of gearing and rods and is worked from top platform, and its hand wheel is marked "H. P. Suction from Main Drain Well." There are, also, two 6-inch branches with 6-inch angle check valves, leading from the secondary drain up through the inner bottom to the after ends of the main drain valve. In case of derangement to the main drain valves, the bilge can be drained through these valves into the main drain wells. All compartments in the double bottom have separate 4-inch suction pipes. All compartments forward of No. B 86 drain through the manifolds in fire rooms Nos. 1 and 2. All compartments from No. B 86 to No. C 92 inclusive, drain through the manifold on forward bulkhead, port engine room, while all compartments aft of No. C 92 drain into the manifold on starboard engine room bulkhead, after end. The only compartments that have not pipes leading direct to the manifolds are trimming tanks Nos. 1 and 4; these drain through sluice gates into trimming tanks Nos. 2 and 3, which are connected to the manifold by 4-inch pipes. All sluice gates above the double bottom are marked "Drain Valves" in the deck sockets, and all sluice gates in the double bottom and to trimming tanks Nos. 1 and 4 are marked "Sluice Gates" in deck sockets.

The following pumps connect with the secondary drain system.

5 7-inch hand pumps.
4 auxiliary pumps in main fire rooms.
1 auxiliary pump in auxiliary fire room.
4 fire and bilge pumps.

Length between perpendiculars on L.W.L., feet and inches	348–1½
over all, including rudder, feet and inches	351–2
Beam, extreme, feet and inches	69–3
at L.W.L., feet and inches	69–3
Ratio of length to beam	5
Depth of hold from top of main deck beams to top of floor, feet and inches	32–1
Height of superstructure above main deck beams, feet and inches	7–4
Draught, seagoing trim, forward, feet and inches	27–0.88
aft, feet and inches	26–5.08
mean, feet and inches	26–8.98
Displacement, seagoing trim, load draught, tons	11,718.96
per inch at L.W.L., tons	42 84
Area of immersed midship section, square feet	1,681
L.W.L. plane, square feet	17,992.8
Center of gravity of L.W.L. plane forward of midship section, (frame No. 45), inches	9⅜
Center of bouyancy above bottom of keel, feet	14.68
forward of midship section, feet and inches	1–11½
gravity above bottom of keel, feet	24.4853
Transverse metacenter above center of bouyancy, feet	28.175
Longitudinal metacenter above center of bouyancy, feet	337.32
Metacentric height, transverse, feet	3.6897
longitudinal, feet	352
Coefficient of fineness, block	.621
of midship section	.928
of L.W.L.	.748
Prismatic coefficient	.668
Number of frames	91
Water tight compartments, (45 of them in D. B.)	249
Wetted surface, square feet	29,890

The following complement of boats is stowed on the superstructure deck:

1 33-foot steam launch.
2 29-foot whale boats.
1 30-foot steam cutter.
1 32-foot sailing launch.
2 28-foot cutters.
1 26-foot cutter.
1 24-foot cutter.
2 20-foot dinghys.
1 balsa.

ARMOR.

Side.—The side armor is of harveyized nickel steel, 18 inches thick from the top to 12 inches below the water line, tapering thence to a thickness of 8 inches at its abutment with the armor

shelf; amidship it extends vertically a distance of 3 feet above and 4 feet 6 inches below the normal load line, gradually tapering towards the ends, to a depth of 4 feet $2\frac{7}{8}$ inches forward and 4 feet $3\frac{1}{4}$ inches aft. It extends over a length of 149 feet, affording protection to machinery and boilers. From the ends of the side armor a diagonal armor of nickel steel, 14 inches thick, extends to the forward and after sides of the 13-inch barbettes, (to which it is concentric amidships,) and forms the ends of the citadel. The citadel is covered with a nickel steel plate, $1\frac{3}{4}$ inches thick, backed by $2\frac{1}{2}$-inch steel plates. Forward and aft of the citadel, the armor deck is made up of two $1\frac{1}{2}$-inch nickel steel plates.

Casemate.—The casemate armor is also of nickel steel, 4 inches thick, and backed by $2\frac{1}{2}$-inch plates. It extends vertically from the top edge of the side armor to the main deck, horizontally from frames Nos. 33 to 60, and then diagonally to 13-inch barbettes.

Conning Tower.—The conning tower is located at the base of the military mast upon the superstructure deck.

All openings in armor deck over machinery and boilers are protected by armor bar gratings.

The following is a list of the armor for the 13-inch and 8-inch turrets, the 6-inch, 6-pounder and 1-pounder guns, conning tower and armor tube.

Object.	Material.	Thickness in inches.	Cover thickness in inches.	Sighting hood, thickness, top and bottom.	Sighting hood cover, thickness in inches.	Diameter, internal, inches.
13-inch turrets....	Harveyized nickel steel.	15	$2\frac{1}{2}$	$5\frac{1}{2}$ and 9	$1\frac{3}{4}$	358
13-inch barbettes.	Harveyized nickel steel.	17	...	...	...	381
8-inch turrets....	Harveyized nickel steel.	6	2	$4\frac{1}{2}$ and 6	$1\frac{1}{2}$	197
8-inch barbettes.	Harveyized nickel steel.	8 at front. 6 at back.	...	...	...	210
8-in. turret tube.	.....	3	...	...	...	55
6-inch gun.....	Nickel steel.	4	...	...	...	...
	Two $\frac{1}{2}$-inch steel plates.	1 } 5				
6-pounder guns.	Nickel steel.	2	...	...	...	...
1-pounder guns.	Nickel steel.	$1\frac{1}{2}$	...	...	...	...
	Plate steel, $\frac{1}{2}$-in. plates.	$\frac{1}{2}$ } 2				
Conning tower...	Nickel steel.	10	...	...	...	83
Armor tube.....	Nickel steel.	7	...	...	...	12

ARMAMENT.

Main Battery.—Two 13-inch B.L.R., 35 cal., mounted in forward turret; two 13-inch B.L.R., 35 cal., mounted in after turret; four 8-inch B.L.R., 35 cal., mounted in two forward turrets on superstructure deck; four 8-inch B.L.R., 35 cal., mounted in two after turrets on superstructure deck; four 6-inch B.L.R., 35 cal., two on each side within superstructure on main deck.

Secondary Battery.—Twenty 6-pounder and six 1-pounder Hotchkiss rapid fire guns; and four light machine guns in the military tops.

Weight of broadside discharge from main and secondary batteries, 5,664 pounds. Weight of one complete discharge, 6,926 pounds.

Torpedo Tubes.—On the berth deck there are six tubes for Whitehead torpedoes; one in the bow, one in the stern, and two on each side. In order to make one additional state room for the junior officers, the port after broadside tube has been removed, but is held in readiness for reinstallation when needed.

MAIN ENGINES.

There are two triple expansion engines of the inverted, direct acting type, placed side by side in separate water tight compartments. The compartments are connected at the forward end of the lower platform by water tight doors opening into the air lock at that point, and at the after end of the middle platform, by one water tight door in the central bulkhead. All the cylinders are fitted with liners; the I.P. and L.P. cylinders are steam jacketed on the sides and bottoms, the H.P. cylinder is not steam jacketed. The H.P. cylinders have one valve each which takes steam in the center; the I.P. cylinder has two, and the L.P. cylinder four, all of these taking steam at the ends. All of the valves are of the piston type, single ported, and are fitted with balance pistons. The valve gear is of the Stephenson type with double bar links, the maximum cut off with the link in full gear being .7 of the stroke. By means of the "gag" in the reverse arms, the cut off can be varied from .4 to .7 of the stroke.

TRIPLE-EXPANSION ENGINE OF THE U. S. "OREGON."

The engine framing consists of a built up, inverted Y frame at the back, and of two solid forged steel columns at the front of each cylinder. The sides of the Y frames are of wrought iron, between which are bolted cast-iron center pieces, the outboard faces of which are the crosshead guide, provided with suitable passages at the back for water circulation and with flanges to which the backing guides are secured. The backing guides are of cast iron, and are secured by through bolts to the main guides. The bed plates are of bronze, in three sections, and each is secured to the engine seating by one hundred and twenty-four $1\frac{1}{8}$-inch and forty-eight $1\frac{1}{4}$-inch steel studs, screwed through the seating and fitted with one nut and split pin at the lower ends; at the upper end, with the exceptions of those coming immediately under the main bearings, two nuts and a split pin are fitted to each stud. The eccentrics are in two parts, the back being of forged steel and the front of cast iron, securely bolted together by two steel bolts and nuts. The backing eccentric is keyed fast to the crank shaft and has the go-ahead eccentric bolted to it, suitable provision being made for a limited movement of this eccentric. The eccentric straps are of composition, lined with Parson's mental. The eccentric rods, links, link blocks, valve stems, drag links, reverse shaft, piston rods, connecting rods and crossheads are of forged steel. The crosshead slipper is of bronze, both working faces being faced with Parson's metal. The main pistons are of cast steel, coned, and each one is fitted with two cast-iron packing rings, $1\frac{1}{4}$ inches wide by $\frac{7}{8}$ inch thick, set out by light ⌒ steel springs. The receiver system is principally external and consists of copper piping and composition branches.

The steam reversing gear consists of a steam cylinder, 14 inches in diameter, and a hydraulic controlling cylinder, $7\frac{1}{2}$ inches in diameter, with a stroke of about 26 inches. The reversing engine is secured at the back of the I.P. cylinder, the steam cylinder being at the bottom. The steam valve and the by-pass in the passage way of the hydraulic cylinder move in unison by means of a floating lever, which receives its primary movement from the hand lever at working platform and its secondary mo-

tion from the reverse shaft by means of a pin and link. A locking cock, for preventing passage from end to end of hydraulic cylinder, is also operated from working platform, and an oil pump for reversing by hand is placed at the base of the I.P. cylinder column. For each main engine there is a double cylinder, inverted turning engine, 6-inch by 6-inch steam cylinders, fitted with a change valve for reversing. The worm on engine shaft gears with a worm wheel at the upper end of a vertical intermediate shaft terminating in a second worm; this second worm can be swung in or out of gear with a worm wheel bolted to forward coupling of the H.P. crank shaft. The engine is secured to main engine seating just forward of the bed plate. For turning by hand, a ratchet can be applied to the upper end of the intermediate shaft.

Steam Piping.—The main steam pipe in fire rooms is 9 inches in diameter, No. 3 B.W.G., with 9-inch branches, No. 2 B.W.G., leading from each boiler. The mains and the branches from after boilers lead to a composition breeches pipe that connects with the 12-inch gate valves on after bulkhead in fire rooms Nos. 7 and 8. The cross connecting pipe in the engine rooms is 10 inches in diameter, No. 1 B.W.G., and is fitted with 10-inch gate valves at its junctures with the main separators; the pipes leading from the separators to throttles are 12 inches in diameter, No. 00 B.W.G. All of the main steam piping is banded with flat steel bands, spaced six inches apart. The auxiliary steam pipe is 5 inches in diameter, No. 6 B.W.G., and is not banded. The main and auxiliary stop valves in the main boilers, together with the safety valves, can be operated from the berth deck as well as from below. The 12-inch main boiler stop valves in after fire rooms can also be worked from the engine room.

The trottle is of the gridiron type, actuated by a vertical crank shaft fitted with a segmental worm wheel, gearing with a worm on hand wheel shaft at working platform. There is, also, an auxiliary $2\frac{1}{2}$-inch throttle, admitting steam to the under side of the main throttle, with hand wheel at working platform.

Four distributing oil tanks are located in each engine room, and are supplied from the main tanks by a hand pump in the

shaft alley. An elaborate system of oil boxes and drop sight lubricators, with pipes leading to all necessary points, is fitted.

Number of cylinders (for one engine)	3	
Diameter of cylinders, H.P., inches	34½	
I.P., inches	48	
L.P., inches	75	
Stroke of all pistons, inches	42	
Diameter of piston valves, H.P. (one), inches	17	
I.P. (two), inches	17	
L.P. (four), inches	17	
	Port.	*Starboard.*
Area of steam ports, H.P., top, square inches	113	111
bottom, square inches	138	138
Maximum opening for ahead motion, I.P., top, square inches	246	221
bottom, square inches	266	255
L.P., top, square inches	408	419
bottom, square inches	466	470
Area of exhaust port, H.P., top, square inches	139	139
bottom, square inches	138	138
Maximum opening for ahead motion, I.P., top, square inches	139	139
bottom, square inches	138	138
L.P., top, square inches	528	528
bottom, square inches	696	696
Area of main steam pipe at engine (twelve inches diameter), square inches	113	
Area of opening (maximum) through gridiron throttle, square inches	175	
Area of opening through 2½-inch auxiliary throttle, square inches	4.9	
Area of main exhaust pipes, (two, 20½ inches diameter), square inches	654.8	
Volume, mean, displaced by piston, per stroke, cubic feet, H.P.	22.23	
I.P.	43.52	
L.P.	106.89	
Ratio of net piston areas, H.P. to I.P.	1.957	
I.P. to L.P.	2.455	
H.P. to L.P.	4.697	
Clearance of H.P. cylinders, per cent., port, top	15.6	
bottom	13.8	
starboard, top	14.4	
bottom	14.0	
Clearance of I.P. cylinders, per cent., port, top	14.1	
bottom	18.9	
starboard, top	14.9	
bottom	18.3	
Clearance of L.P. cylinders, per cent., port, top	14.0	
bottom	14.7	
starboard, top	13.3	
bottom	16.3	

Piston rods, diameter, inches	7⅛
length from collar to shoulder, feet and inches	5–5½
length over all, feet and inches	8–3
Connecting rods, length from center to center, feet	7
diameter of upper end, inches	6⅝
diameter of lower end, inches	8½
thickness (sides as faced), inches	6⅝
crosshead bolts (4), diameter, inches	3
crankpin bolts (2), diameter, inches	4¼
Crosshead pins, diameter, inches	7½
length, inches	9
slipper surface, ahead, square inches	393·5
surface, backing, square inches	257
Valve stems, H.P. (1), I.P. (2), L.P. (4), diameter through balance pistons, inches	1½
diameter through valve, inches	2
through stuffing box, ins.	2⅝
Balance pistons, diameter, inches, H.P. and I.P.	5¼
L.P.	7
Reversing gear (steam), steam cylinder, diameter, inches	14
water cylinder, diameter, inches	7½
piston rod (steam) diameter, inches	2½
water, diameter, inches	3⅛
Reversing gear (hand), pump, diameter, inches	1¼
stroke, inches	5
Turning engine, number of cylinders	2
diameter of cylinders, inches	6
stroke of cyliuders, inches	6

worm on engine shaft, double thread, pitch diameter, $5\frac{1}{16}$ inches; pitch, $2\frac{3}{4}$ inches.

worm on intermediate shaft, pitch, 3 inches; pitch diameter, $7\frac{1}{2}$ inches.

worm wheel on intermediate shaft, pitch, $1\frac{3}{8}$ inches; pitch diameter, $15\frac{1}{16}$ inches; $2\frac{1}{2}$ inches face.

worm wheel (turning), pitch, 3 inches; pitch diameter, 4 feet $9\frac{1}{4}$ inches; $5\frac{1}{2}$ inches face.

Shafting and Bearings.—All the shafting is of forged steel with an axial hole. The crank shafts are in three sections, which are interchangeable, with the exception of one section, which is $\frac{11}{16}$ inch shorter than the others. The crank pins are also hollow, and the sequence of the cranks is L.P., I.P. and H.P. for the ahead-going motion. All coupling bolts are parallel. Each line shaft is in two sections and has three bearings. The propeller

shafts have solid couplings on the inboard end and are cased with composition for a distance of 31 feet 3 inches.

The thrust bearings are of the horse shoe type. The pedestal is formed into an oil well, and has adjustable bearings at each end to take the weight of the shaft, and stuffing boxes for retaining the oil. The end bearings and horse shoes are faced with Parson's metal. The pedestal is bolted to a plate steel seating built into the ship.

Crank shafting, throw, inches	21
diameter, inches	14
number of sections for one engine	3
length of each section, feet and inches	8–7
coupling disc, diameter, inches	26½
thickness, inches	3¼
number of bolts in each disc	6
diameter of coupling bolts, inches	3½
journals, length, inches	17⅜
diameter, inches	14
diameter of axial hole, inches	6
Crank pins, diameter, inches	15
length, inches	17
diameter of axial hole, inches	6½
Crank webs, width, inches	15¾
thickness, inches	9½
Thrust shaft, diameter, inches	12¾
length, feet and inches	19–3
diameter of coupling discs, inches	26½
thickness of coupling discs, inches	3¼
collars, number of to each shaft	11
greatest diameter, inches	18¾
least diameter, inches	14
thickness, inches	2
distance between, inches	4
surface, total for one engine, square inches	2,332 64
axial hole, diameter, inches	6
Line shafting, length of two sections (total), feet and inches	38–3
diameter, inches	13¾
of coupling, inches	26½
of coupling bolts, inches	3½
number of coupling bolts	6
diameter of hole, inches	6
Propeller shafting, length of one section (total), feet and inches	38–9½
diameter, inches	14

Propeller shafting, diameter of coupling, inches	26½
of hole, inches	6
Stern tube bearing, length of each forward and after section, feet and inches	3–2¼
bracket bearing, length, feet and inches	3–6¾
diameter, inches	15¾

Screw Propellers.—The propellers are three-bladed, adjustable, with axially expanding pitch. The hubs are spherical and terminate in a conical tail piece. The blades are bent backwards 6 inches at the tips, and the material is manganese bronze.

Diameter of propeller, feet	15
hub, feet and inches	4–2
Length of hub, feet and inches	3–4
Form of blade	Modified Griffith.
Number of blades	3
Greatest width of blade, 4 feet 3 inches from center, feet and inches,	4–8½
Greatest length of blade, 3 feet from center, feet and inches	2–8¼
Number of studs in one blade	7
Diameter of studs, inches	3⅞
Pitch entering, feet	15
Pitch leaving, feet	17
Pitch, mean, feet	16
Pitch adjustable, in feet and inches, from	15–6 to 16–6
Pitch set on trial, feet and inches	15–6
Helicoidal area of 3 blades, square feet	66
Projected area of 3 blades, square feet	55.41
Disc area of one screw, square feet	176 7
Ratio of mean pitch to diameter	1.066
Ratio of disc area of two screws to area of immersed midship section	0.23
Immersion of center of propeller at 24 feet draught, feet	8.06

Main Condensers.—In each engine room there is one main condenser of cast brass in four sections, the heads being additional. Baffle and supporting plates are fitted, and the water flows through the tubes. The after head is fitted with four doors and the forward head with three circular man holes. The circulating pipe nozzles are so arranged that these doors can be removed for the examination of the tubes without disconnecting the circulating pipe.

Diameter of shell, inside, feet and inches	5–9
Thickness of shell, inch	$\frac{7}{8}$
Length over all, feet and inches	12–5$\frac{1}{4}$
between tube sheets, feet and inches	10–3
Tubes, outside diameter, inch	$\frac{5}{8}$
thickness, No. 18 B.W.G., inch	.049
number in each condenser	3,788
Cooling surface, each condenser, square feet	6,352.5
total, square feet	12,705.0
Ratio of total cooling to total heating surface, main boilers	1.325
and auxiliary boilers,	1.476

Main Air Pumps.—For each main engine there is one double, vertical, single acting, geared air pump driven by a pair of simple engines.

Number of steam cylinders	2
water cylinders	2
Diameter of steam cylinders, inches	6
pump cylinders, inches	20
piston rod, steam, inches	1$\frac{3}{8}$
piston rod, water, inches	3
foot valves (10), inches	5
bucket valves (8), inches	5
head valves (8), inches	5
Stroke of steam cylinders, inches	12
water cylinders, inches	20
Area through foot valves (10), square inches	103.5
bucket valves (8), square inches	82.8
head valves (8), square inches	82.8
Ratio of area through foot valves to area of pump cylinder (1)	0.329
Ratio of gearing	1 to 2.51

Main Circulating Pump.—There is one centrifugal, double inlet circulating pump for each main engine, driven by a vertical, direct acting, compound engine. It has a suction from the sea, main drain well and from engine room bilge.

Number of steam cylinders	2
Stroke, inches	6
Diameter of steam cylinders, inches	7$\frac{1}{2}$ and 12
piston rods, inches	1$\frac{3}{8}$
runner, inches	36
inlet in runner, inches	17
inlet nozzle (two), inches	15$\frac{1}{2}$

Diameter of discharge nozzle, inches	17
main injection, inches	15
drain well injection, inches	12
engine room bilge injection, inches	12
Width of runner at center, inches	7
rim, inches	3

Hot Well Pumps.—The hot well pumps are two in number; vertical, double acting (Dow), of 582.3 gallons per minute capacity each, and located one in each engine room. They draw from the hot wells, main condensers and drain tanks, and deliver into the feed tanks, only.

Auxiliary Condenser.—Connecting with the auxiliary exhaust system in each engine room, there is an auxiliary condenser, cylindrical in form, with the steam passing around tubes. Each condenser is fitted with a horizontal combined air and circulating pump of the Dow pattern.

Length over all, feet and inches	7–3
Length between tube sheets, feet and inches	5–10
Number and size of tubes (477), No. 18 B.W.G., inch	$\frac{5}{8}$
Cooling surface, one condenser, square feet	449
Diameter of condenser, inside, inches	$24\frac{1}{2}$
steam cylinder, inches	8
water cylinder (circulating), inches	9
air cylinder, inches	11
Stroke of pumps, common, inches	10

MAIN BOILERS.

There are four double ended steel boilers of the horizontal fire tube type, placed fore and aft in four water tight compartments, with a midship passageway extending throughout the boiler space. This passageway is divided into four compartments, and has water tight doors leading into the fire rooms, forward hydraulic pump room and into an air lock at forward end of engine rooms.

Each boiler has eight corrugated furnaces and four combustion chambers. The tubes are of steel and protected at inner ends from the flame by wrought-iron rings let into the back tube sheets. The shells are each in three courses of three plates, fitted with double butt straps, treble riveted longitudinally, with

every other rivet omitted in the outside rows. The circumferential seams are lapped and treble riveted in the center and double riveted at the ends. The heads are curved at the top to a radius of 3 feet $9\frac{3}{4}$ inches. Each boiler has three $4\frac{1}{2}$-inch safety valves in a common case, and fitted so as to be worked from the berth deck or fire rooms. Two Weir's hydrokineters are fitted to each boiler, and steam from the auxiliary boilers can be used for circulation if so desired. Water circulation in the boilers can also be accomplished by the auxiliary feed pumps.

FOUR MAIN BOILERS.

Details for one boiler.

Test pressure, pounds per square inch	250
Steam pressure, pounds per square inch	160
Diameter, outside, feet	15
Length, feet	18
Diameter of furnaces, inside, feet	3
outside, feet and inches	3–4
Number of furnaces, corrugated	8
Exposed length of grate, feet and inches	5–6
Length of grate over all, feet and inches	5–9
Tubes, number of ordinary, No. 12 B.W.G.	672
stay, No. 6 B.W.G	244
outside diameter, inches	$2\frac{1}{2}$
length between tube sheets, feet and inches	6–$0\frac{3}{8}$
spaced vertically, inches	$3\frac{3}{4}$
horizontally, inches	$3\frac{1}{2}$
length of tubes as ordered, feet and inches	6–$2\frac{1}{2}$
Combustion chambers, number	4
length, top, inches	$27\frac{1}{2}$
bottom, inches	30
Thickness of shell plates, inches	$1\frac{9}{64}$
heads, top plate, inches	$1\frac{9}{64}$
bottom plate, inch	$\frac{3}{4}$
furnaces, inch	$\frac{1}{2}$
combustion chambers, inch	$\frac{1}{2}$
back tube sheet, inch	$\frac{3}{4}$
front tube sheet, inch	$\frac{7}{8}$
Braces, number and diameter of around lower manholes, inches	12 of $1\frac{5}{8}$
from head to back tube sheet, ins.	6 of $2\frac{1}{8}$, 4 of $1\frac{3}{4}$
through braces below tubes, ins.	1 of 2, and 1 of $1\frac{5}{8}$
above tubes, ins.	10 of $2\frac{1}{8}$
pitch of, above tubes, inches	15

Screw stays, diameter of, body, inches	$1\frac{9}{16}$
pitch of, inches	7
Heating surface, total, square feet	4,208
tube, square feet	3,696
furnaces, square feet	276
combustion chambers above brick work, square feet	336
Height of smoke pipes above lower end of grate, feet and inches, forward,	69–10$\frac{6}{8}$
aft	70–0$\frac{3}{8}$
Diameter of forward smoke pipe, feet and inches	7–9
auxiliary boiler smoke pipe, feet and inches	3–6
after smoke pipe, feet	7
Area of grate surface, square feet	138
over bridge wall, square feet	18.5
through tubes, square feet	23.2
forward smoke pipe (net), square feet	37.6
after smoke pipe, square feet	38.5
Volume of furnaces above grates and of combustion chambers above brick work, cubic feet	497.2
Water surface, 6 inches above tops of combustion chambers, square feet	210
Steam room, 6 inches above tops of combustion chambers, cubic feet	569
Diameter and number of safety valves in one case, inches	3 of $4\frac{1}{2}$
Load on safety valves during trial, pounds per square inch	168
Diameter of stop valves on main boiler, inches	9
auxiliary stop valve on main boilers, inches	5

TOTALS FOR FOUR BOILERS.

Heating surface, total, square feet	16,832
tube, square feet	14,784
plate, square feet	2,448
Grate surface, square feet	552
Area over bridge walls, square feet	74
through tubes (net), square feet	92.8
of water surface, square feet	1,144
Volume of steam room, cubic feet	2,276
of furnaces and combustion chambers above grates and brick work, cubic feet	1,988.8
Ratios, total H.S. to G.S.	30.51 to 1
tube H.S. to G.S.	26.78 to 1
plate H.S. to G.S.	4.43 to 1
area through tubes to G.S.	.168 to 1
steam room, per square foot of grate	4.12 to 1
volume of combustion chamber above brick work and furnaces above grates to G.S.	3.6 to 1
Rivets, pitch of longitudinal seams, inches	$8\frac{23}{32}$
circumferential seams, middle, inches	$4\frac{13}{16}$
ends, inches	$3\frac{17}{32}$

Diameter of rivets, actual, longitudinal seams, inches	1¼
circumferential seams, middle, inches	1⅜
ends, inches	1¼
Strength of joint, plate, per cent	84.95
rivets, per cent	86.6

Forced Draft.—For the main boilers, the closed fire room system is used, the air being furnished by eight Union Iron Works' centrifugal blowers. The blowers are located one in each fire room and are driven by an inverted, compound engine, enclosed in a dust tight case. For the auxiliary boilers, the closed ash pit system is used; the air is supplied by one blower and engine of the same size and pattern as for the main boilers, and is passed through air ducts to housings around the furnace doors. Suitable valves are provided for admitting the air both above and below the grates.

BLOWERS AND ENGINES FOR MAIN AND AUXILIARY BOILERS.

Number for main boilers	8
auxiliary boilers	1
Diameter of blowers, feet	5
inlet rings (2) in casing, feet and inches	2.9
Width of blower at center, inches	16¼
tip, inches	9⅝
Area of induction, square feet	11.88
discharge, square feet	13.5
Diameter of steam cylinders, inches	5½ and 7
piston rod, inches	1¼
Stroke, inches	6

Feed Pumps.—In each of the feed pump fire rooms (Nos. 3, 4, 5 and 6) there are two vertical, double acting Dow pumps, each of a capacity of 253 gallons per minute, one for the main and one for the auxiliary feed systems. The two systems are connected so that any pump can be used to supply each and all of the main boilers.

The main feed pumps draw from the feed tanks and deliver to the boilers only. The auxiliary feed pumps draw from the sea, feed tank, boilers, secondary drain, and a small drain well at the after ends of the main boilers, and deliver into the boilers, sea, fire main and overboard.

Feed Tanks.—Adjacent to the central passage and extending through the after thwartship bunkers there are two feed tanks of 2,250 gallons' capacity each. The upper portion of each tank is arranged for a filter, and doors are provided for admission into the filter and water spaces. The tanks are covered with asbestos and cased with light galvanized sheet iron, and are fitted with an overflow pipe leading into the bilge, a vapor pipe, water glass gauges, zinc blocks, hydrokineters for circulating the water, and a double disc valve with float to prevent air entering the feed pump suctions. This valve can also be worked by a lever in the passageway.

AUXILIARY BOILERS.

There are two auxiliary single ended steel boilers located forward on the orlop deck in one compartment with a fore-and-aft fire room. The shells are in two courses of two plates each. The heads are in two parts and the upper portions are curved to a radius of 2 feet 2½ inches in front, and to 2 feet 1⅝ inches at the back. Each boiler is fitted with a Weir's hydrokineter, and the auxiliary feed pumps can also be used for circulating the water in the boilers. These boilers are fitted with the closed ash pit system, as before described.

AUXILIARY BOILERS.

Number of boilers	2
Steam pressure, pounds per square inch	160
Diameter outside, feet	10
Length, feet and inches	8–6
Diameter of furnaces, inside, feet and inches	2–9
Diameter of furnaces, outside, feet and inches	3–1
Number of furnaces, one boiler	2
Exposed length of grate, feet and inches	5–9
Length of grate over all, feet	6
Tubes, steel, number of ordinary, No. 12, B.W.G.	156
stay, No. 6, B.W.G.	58
outside diameter, inches	2¼
length of, between tube sheets, feet and inches	5–8½
spaced, horizontally, inches	3⅜
vertically, inches	3½
length as ordered, feet and inches	5–10½
Combustion chambers, number of	2

Combustion chambers, height above brick work, feet and inches	4–0¾
center of furnace, feet and inches	4–6¼
length, top, inches	23¼
bottom, inches	24¾
Thickness of shell plates, inch	5/8
heads, top plate, inch	11/16
bottom plate, inch	¾
furnaces, inch	13/32
combustion chambers, inch	½
back tube sheet, inch	¾
Braces, number and diameters around lower manhole, inches	2 of 1½
from head to back tube sheet, inches	2 of 2
through braces below tubes, inches	2 of 1¾
above tubes, inches	8 of 2
pitch of, above tubes, 13 inches (center); 12 inches; 12½ inches; 12½ inches (outboard).	
Heating surface, total, square feet	961
tube, square feet	817
furnaces, square feet	60
combustion chambers, square feet	84
Screw stays, diameter of body, inches	1 3/16
pitch	7
Smoke pipes, height above lower end of grates, feet and inches	46–6
diameter, feet and inches	3–6
dimension of duct, inside, feet and inches	3–4 by 2–9
Area of grate surface, square feet	32
over bridge wall, square feet	3.56
through tubes, square feet	5 8
through duct, square feet	8.47
through smoke pipes, square feet	9.62
Volume of furnaces above grates and combustion chambers above brick work, cubic feet	99
Volume of steam room, 6 inches above top of combustion chambers, cubic feet	116
Water surface, 6 inches above top of combustion chambers, square feet	72
Number and diameter of safety valves in one case, inches	2 of 3
Load on safety valve, during trial, pounds per square inch	168
Diameter of stop valves, inches	5
Rivets, pitch, longitudinal seams, inches	6 3/16
circumferential seams, center, inches	3 7/32
ends, inches	3¼
Diameter, actual, of rivets, longitudinal seams, inches	1 1/32
circumferential seams, center	1 7/32
ends	1⅛
Strength of joint, plate, per cent.	83
rivets, per cent	87

TOTALS FOR TWO BOILERS.

Heating surface, total, square feet	1,922
tube, square feet	1,634
plate, square feet	288
Grate surface, square feet	64
Area over bridge walls, square feet	7.12
through tubes, square feet	11.6
of water surface, square feet	144
Volume of steam room, cubic feet	232
furnaces above grates and combustion chambers above brick work, cubic feet	198
Ratios:	
Total H.S. to G.S	30 03 to 1
Tube H.S. to G.S	25.53 to 1
Plate H.S. to G.S	4.5 to 1
Area through tubes to G. S	.181 to 1
Steam room per square foot of grate	3.62 to 1
Volume of combustion chamber above brick work and furnaces above grates to G.S	3.09 to 1

TOTALS FOR ALL BOILERS.

Tube heating surface, square feet	16,418
Plate heating surface, square feet	2,736
Total heating surface, square feet	18.754
Area through tubes, square feet	104.4
Grate surface, square feet	716
Steam room, cubic feet	2,508

RATIOS, ALL BOILERS.

Tube H.S. to G.S	22.93 to 1
Total H.S. to G.S	26.19 to 1
Area through tubes to G.S	.146 to 1
Steam room per square foot of G.S	3.36 to 1

Fire and Bilge Pumps.—In each engine room there are two vertical, double acting Dow pumps, each of a capacity of 254.6 gallons per minute. The suction pipes of these pumps connect to a manifold just forward of the air pumps below the engine-room floor; through this manifold connection is made with the sea, main drain cistern, hot well, engine room drain well, and, through compartment manifolds on the engine room bulkheads, with the secondary drainage system. There is also a separate suction to the shaft alley drain wells. They discharge through a manifold into the fire main, feed tanks and overboard.

LIST OF DOW PUMPS ON THE *U. S. S. OREGON*.

Number of pumps.	Diameter of steam cylinder.	Diameter of water cylinder.	Diameter of air cylinder.	Stroke of all cylinders.	Class.	Displacement in gallons for one double stroke. Water.	Displacement in cubic inches for one double stroke. Air.	For what purpose used.
	Inch.	*Inch.*	*Inch.*	*Inch.*				
4	12	8	...	12	Single, vertical piston	Each 5.06	.....	Main feed, main boilers.
4	12	8	...	12	Single, vertical piston	Each 5.06	.....	Auxiliary feed, main boilers.
2	12	8	...	12	Single, vertical piston	Each 5.06	.....	Water service.
1	8	8	8	10	Horizontal air and circulating pump	.....	.....	Evaporator.
2	8	9	11	10	Horizontal air and circulating pump	Each 5.44	1886.0	Auxiliary condenser.
2	10	6	...	12	Single, vertical piston	Each 2.81	.....	Auxiliary boiler feed pumps.
4	10	8	...	18	Single, vertical piston	Each 7.64	.....	Fire and bilge pumps.
2	6½	12	...	18	Single, vertical piston	Each 17.47	.....	Hot well pumps.
2	10	4¼–3	...	12	Vertical, duplex, differential plunger	Each 0.73	.....	Hydraulic steering gear pumps.
1	3	2½–2¾	...	3	Horizontal piston	Filter 0.123 Brine 0.095	.....	Filter and brine, distillers and evaporators.
1	4½	7	...	8	Single, vertical piston	2.63	.....	Sanitary pump.
1	4½	4	...	6	Single, horizontal piston	0.64	.....	Fresh water ship's tanks.

NOTE.—The steam ends of the hydraulic pumps for the 13-inch turrets were also made by Dow.

Water Service Pumps.—In each engine room there is one vertical, double acting Dow pump, of a capacity of 253 gallons per minute, which draws from the sea only, and discharges into the water service pipes, fire main, through this main into the sanitary system, and to the accumulators in the 13-inch turret pump rooms. Through a T-piece and separate sea valve, the water service for the main bearing brasses can be maintained while the pump is discharging into the fire main.

Steam Traps.—There are 34 large and small McKellar's traps, distributed as follows: Engine room, 4 large and 10 small; fire rooms, 2 large and 12 small; 13-inch turret hydraulic pump rooms, 2 small; torpedo compressor rooms, 2 small; distiller plant, 2 small; galley, 1 small; dynamo room, 1 large. Through these traps the condensed steam from the main and auxiliary steam pipes, cylinder jackets, separators, radiators, etc., is finally discharged into the drain tanks in engine rooms.

Ash Hoists.—On the main deck there are four, double, simple engines for hoisting the ashes from the main and auxiliary fire rooms. The cylinders are 4 inches in diameter and 6 inches stroke, with a change valve for reversing, and automatic stops to prevent overwinding.

Ventilating Blowers.—For ventilating each engine room, there is one centrifugal Union Iron Works' blower, driven by a vertical, direct acting compound engine.

Diameter of blower, feet	5
central opening, feet	2
Width of blower at center, inches	9
Width of blower at rim, inches	4
Area of induction nozzle, 14x36, square feet	4.98
Area of discharge nozzle, 30x12, square feet	2.5
Diameter of steam cylinders, inches	3½ and 6
Stroke, inches	6
Piston rod, diameter, inches	1

For the general ventilation of the ship there are four blowers located on the berth deck. By means of reversible valves in the air shafts, the blowers can be used for supplying air to or exhausting it from different parts of the vessel. The blowers and engines are the same as those used in the fire rooms.

Engineer's Work Shop.—This work shop is on the armor deck at forward end of engine room, and is immediately under the distilling plant. It is fitted with the following tools: One 12-inch shaper, one 14x40-inch lathe, one No. 4 Dallet drill and one 4x5-inch vertical engine. A substantial work bench, with vises and drawers, is fitted at forward end of work shop.

Distilling Plant.—This plant consists of two Baird evaporators and distillers, having a combined capacity of 5,500 gallons of potable water in twenty-four hours, one combined air and circulating pump, one combined brine and filter pump, two filters, one separator, one water meter, and all necessary valves and pipes and fittings. The circulating water after passing through the distillers is discharged into the salt water tanks on the superstructure deck and thence to the flushing system. By means of by-pass valves, the distillers can be shut off and the circulating pump discharge directly into the salt water tanks. The filter pump draws from the filters and discharges into the ship's fresh water tanks, and through the fresh water tank on deck to the main and auxiliary feed tanks. In the distilling room, there is also a fresh water pump that draws from the ship's tanks below and discharges to the tank on deck, and to the main and auxiliary feed tanks. The brine pump draws from the evaporators and discharges into the main outboard delivery in the port engine room. The drain water from the evaporator passes to the steam drainage system in the fire rooms, and thence into the drain tanks in engine rooms. All of the above pumps are horizontal and Dow's patent.

Telegraphs and Revolution Indicators.—In each engine room there is a mechanical telegraph connected to transmitters in the conning tower, pilot house and bridge, and a mechanical gong with sound pipe and hood, its bell pulls being at the bases of the after search lights on the bridge. In conjunction with the tranmitters in the conning tower, pilot house and bridge, mechanical tell-tales are fitted for indicating the direction in which the engines are turning. In each engine room there is a mechanical indicator, driven from the forward ends of the shafting, for showing the direction and speed of the crank shaft.

Speaking Tubes and Telephones.—In addition to the central station, communicating with all parts of the system, the more important stations are fitted with speaking tubes direct, call bells being attached to all speaking tubes. There is also connection by telephone from the pilot house and bridge to the engine rooms, central station and steering gear (hydraulic). A telephone in the Chief Engineer's room leads directly to the starboard engine room.

Air Compressors.—The compressors for the torpedo tubes are of the Rand Drill Co.'s pattern, each with two 9-inch steam cylinders by 4 inches stroke. The air cylinders are placed above the steam cylinders, and the water cylinders are enclosed in a water jacket. With 50 pounds of steam at throttle and 200 revolutions per minute, these machines have a capacity of 17.4 cubic feet at a working pressure of 1,700 pounds per square inch. The forward compressor is on the lower platform deck, on the port side just forward of the forehold. The after compressor is on the starboard side of same deck and just forward of the steering gear.

Steering Gear (hydraulic).—This gear consists of two rams engaging with a yoke fixed to the head of the rudder post. The working pressure is 600 pounds per square inch and is furnished by two of Dow's vertical duplex-differential plunger pumps of 36.50 gallons' capacity per minute. The pumps are fitted with Dow's combined pressure regulator and governor.

Steam Windlass.—On the main deck forward there is one geared steam windlass, built by the Union Iron Works. It has four wildcats for $2\frac{1}{2}$-inch chain, with clutches and brakes, and is driven by a double, vertical, simple engine with 16 by 12-inch cylinders fitted with a change valve for reversing.

Steam Winches.—In the after end of the windlass casing there is a double 6 by 8-inch winch, with gypsies projecting on either side of the casing. Forward and aft of the 13-inch turrets on the main deck, there are four double winches, with 9 by 8-inch cylinders, change valves for reversing, friction drums and gypsies for rope.

Boat Cranes.—There are two boat cranes driven by geared, double, simple engines, 8 inches diameter by 8 inches stroke.

Steam Boats.—There is one 33-foot steam launch and one 30-foot steam cutter, each fitted with a compound engine (Bureau's design), keel condenser and Ward boiler.

	33-foot launch.	*30-foot cutter.*
Diameter of cylinders, inches	4 and 7	3½ and 7
Stroke, inches	7	6
Propeller, 4 bladed, diameter, inches	28	26
Pitch, true, inches	38	38
Helicoidal area, 4 blades, square inches	320	250

Refrigerating Plant.—The refrigerating room has a volume of 549 cubic feet, is fitted with 169 square feet of cooling surface and is located forward on the main deck, starboard side. The room for the ice machine is directly opposite on the port side. There is a one-ton Allen dense air machine of sufficient capacity to make 200 pounds of ice per day, to cool 300 gallons of water to about 40 degrees, and to keep the temperature of the refrigerating room at about 32 degrees Fahrenheit. The accompanying table gives the results of two trials made with the above plant. The first trial was to test the ice producing capacity of the machine alone. The second trial was to test the ice producing capacity of the machine in conjunction with the refrigerating room.

First Test, June 18.—The machine was started at 7·30 A. M. on the ice box. The cans being filled with fresh water, at 10·40 A. M. the test commenced. It ended at 5·30 P. M., the ice box being left in the same condition as at the start. 198 pounds of ice were made, or at the rate of 691 pounds per day, or 28.8 pounds per hour.

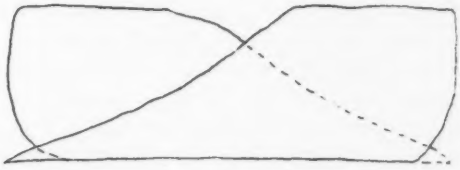
Second Test, June 24.—At 6 P. M. June 23, the machine was put on the ice box and refrigerating room, the cans being filled with fresh water. At 10·30 A. M., June 24, the cans were emptied and refilled and the test commenced; it ended at 3·30 P. M., the ice box being in the same condition as at the start. 125 pounds of ice were made, or at the rate of 600 pounds per day, or 25 pounds per hour.

At 10·45, the temperature of refrigerating room was 32°; at 11·45, 34°; at 12·45, 36°; at 1·45, 36°; at 2·45, 34°; at 3·30, 33°.

Hour.	Pressures.			Temperatures.				Revs.	Pounds of ice.
	Steam.	L.P. air.	H.P. air.	Inj. water.	Dis. water.	Fresh water.	Atmosphere.		
A. M.									
10·40	120	70	240	62	72	73	...	120	
11·10	125	73	255	62	72	73	...	129	
11·40	123	70	250	62	72	72	...	134	
P. M.									
12·10	119	70	257	62	72	72	...	132	
12·40	118	68	270	62	72	72	...	134	
1·10	120	72	262	62	72	72	...	128	34
1·40	120	77	280	62	72	72	...	133	34
2·10	124	80	265	64	74	76	...	102	29
2·40	118	75	250	64	73	76	...	116	
3·10	117	70	246	64	75	75	...	129	
3·40	122	75	265	64	88	74	...	120	
4·10	120	70	245	64	95	74	...	116	34
4·40	118	65	240	62	78	74	...	125	36
5·10	120	75	265	60	70	74	...	124	
5·30	122	75	265	60	70	74	...	126	31
Avr'ge,	120.4	72.3	257.	62.	75.1	73.5	...	124.5	
A. M.									
10·30	140	72	262	65	86	82	70	142	
11·00	126	72	260	65	104	78	70	139	
11·30	135	72	267	63	103	76	70	153	
12·00	140	70	257	62	106	76	71	146	
P. M.									
12·30	149	72	265	61	116	76	71	153	
1·00	145	72	260	61	99	78	72	152	31
1·30	142	72	260	62	102	76	72	144	
2·00	147	72	260	60	108	76	73	144	
2·30	145	72	260	60	102	76	73	140	
3·00	141	72	260	60	104	77	73	140	
3·30	140	72	255	60	102	77	72	144	94
Avr'ge,	140.9	71.8	260.5	61.7	102.9	77.	71.5	145.1	

Turret Machinery.—13-*inch Turrets.*—In each 13-inch turret there are two three-cylinder, single acting, hydraulic engines, $8\frac{3}{4}$ inches in diameter by 10 inches stroke, geared three to one, and designed for a working pressure of 600 pounds per square inch. The engines are secured to the top roller ring, one set on each side, their crank pin centers being 75 degrees from the fore-and-aft line, measured from the muzzle of the guns. There are two pinions on each engine, gearing into a rack bolted to the bottom

STEAM CYLINDERS.



AIR EXPANDER CYLINDER.

AIR COMPRESSOR CYLINDER.

roller ring, through which motion is transmitted to the turret. There is one distributing valve for each pair of engines, and a differential valve with gear for controlling the movement of the turret. The train of the turret is about 280 degrees.

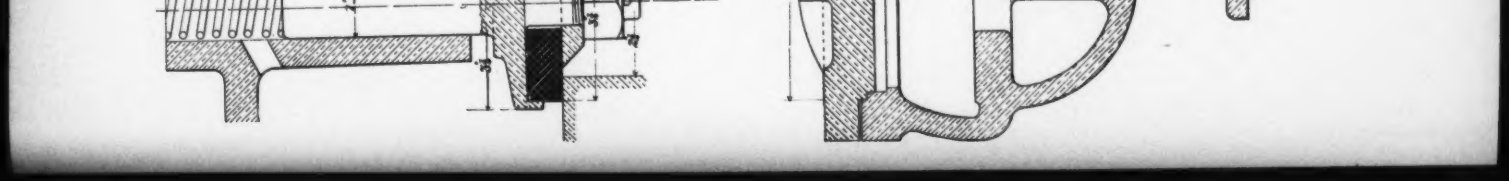
Eight-inch Turrets.—For turning each 8-inch turret there is a two-cylinder simple engine, located in the ammunition passage on the orlop deck. The cylinders are inverted and the framing is securely bolted to the adjacent bulkheads. The motion of the engine is transmitted through bevel gears to two shafts carrying forged steel worms, which engage, on opposite sides, a worm wheel secured to the ammunition tube. A controlling valve is fitted to each engine which can be operated from the turrets and at the engine. The limit of the train is from within 10 degrees of the keel line to 54 degrees forward or abaft the beam, or about 134 degrees. Indicators showing the position of the turrets are fitted in front of the operating gear in the sighting hoods, at bottom of tubes, and on engines. To prevent overtravel of the turrets and controlling valves, automatic stops are fitted at the bottoms of the central tubes. A safety stop (automatic) is also fitted to each engine and so set as to operate a little later than the stops at bottom of tube, in case the latter should carry away.

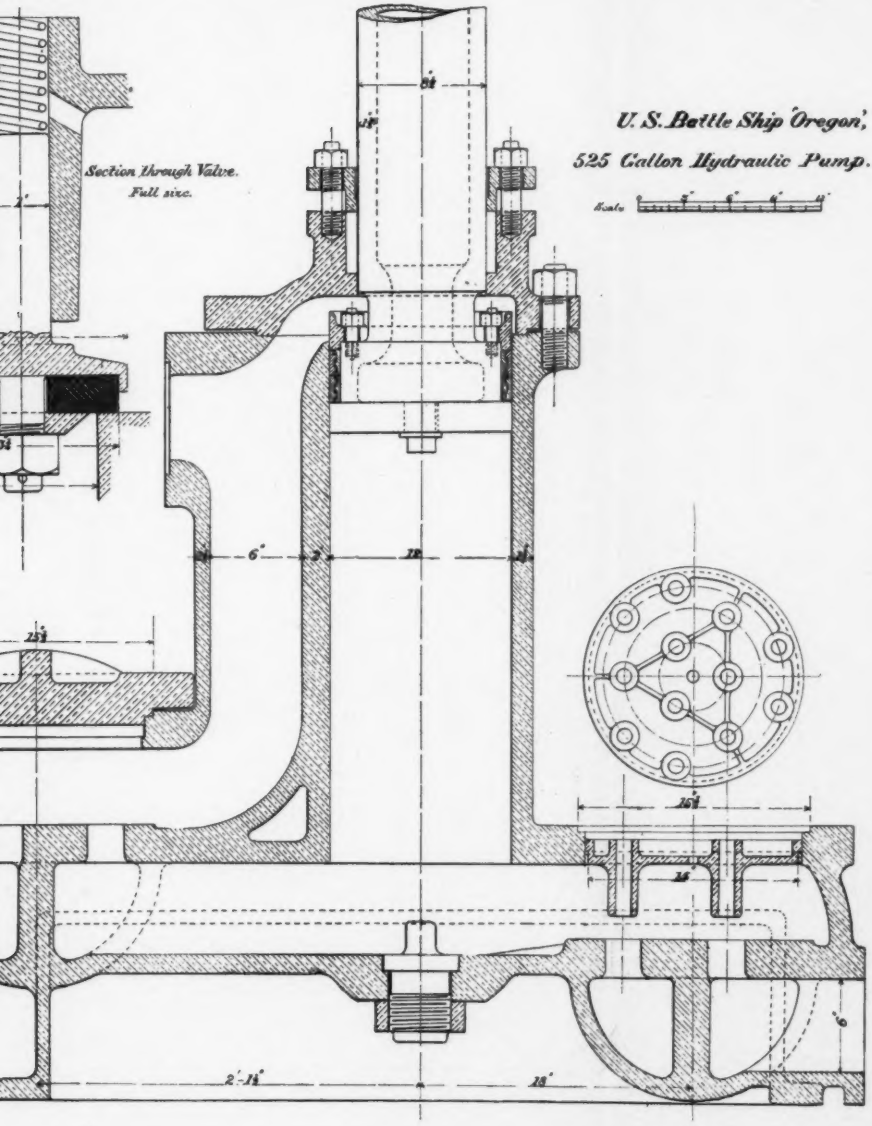
Hydraulic Plant.—For operating the 13-inch guns and revolving their turrets, there are two hydraulic plants, one just forward of the main boilers and the other aft of the engines. Each plant consists of two vertical, differential plunger pumps, driven by steam cylinders fitted with Dow's valve gear, and combined pressure regulator and governor, an accumulator, a water tank and all necessary fittings. The pumps are arranged side by side and deliver into a common discharge to the central column of their respective turrets and accumulators. Through the wing passage on the port side, a 6-inch hydraulic pipe connects the pressure side of the forward and after pumps, while a 6-inch galvanized gas pipe passes through the wing passage on the starboard side and connects the escape from the engines in the forward and after turrets, thus enabling the turret to be operated at will by either set of pumps. Each accumulator is fitted with an air compressor and air pressure chamber, all connected together and

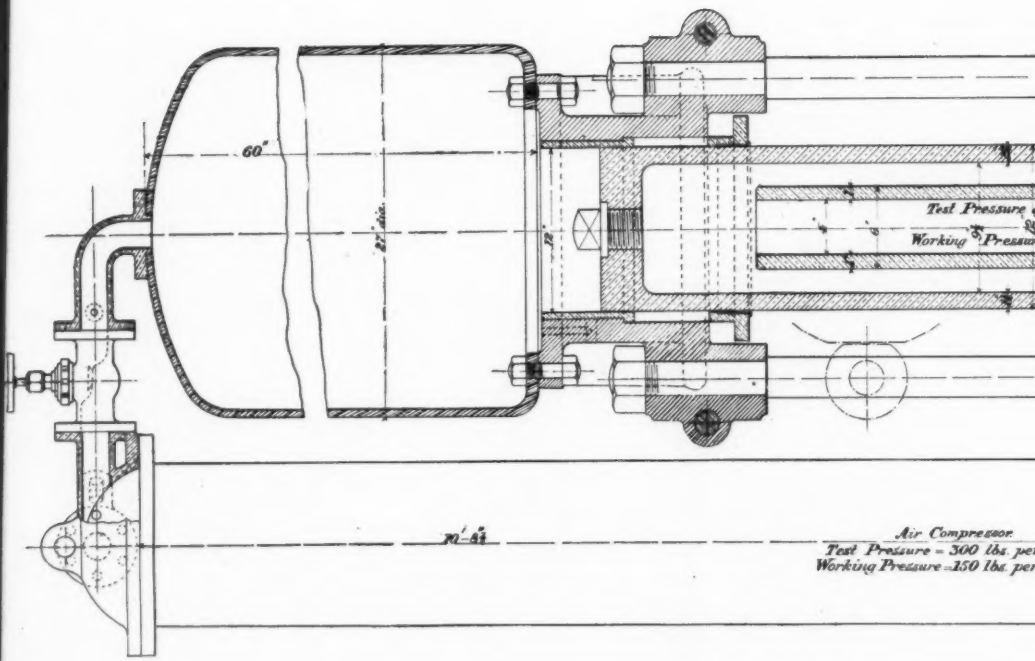
resting upon a common base. The details are shown in the plates. For supplying each plant with fresh water, a tank of 1,000 gallons capacity is fitted in each pump room.

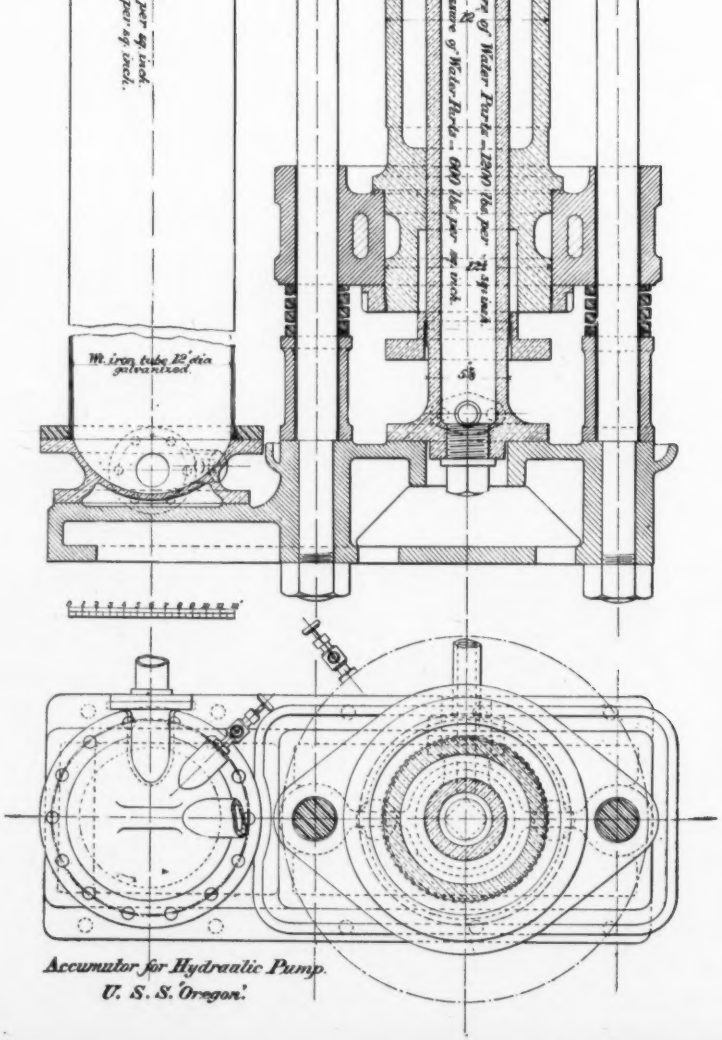
Test pressure, hydraulic, pounds per square inch	1,200
air, pounds per square inch	300
Working pressure, pounds per square inch	600
Number of double strokes per minute	35.74
Capacity of one pump, gallons per minute	525
Steam cylinder, diameter, inches	27
Pump plunger, diameters, inches	12 and 8½
Stroke, common, inches	30
Suction, diameter, inches	6
Discharge, at pump, diameter, inches	5¾
main, diameter, inches	6
Number of suction valves	12
discharge valves	12
Suction and discharge valves, diameter, inches	3¼
Material of valves	Hard rubber.
Accumulator:	
Ram, diameter, inches	12
thickness, inches	1¼
stroke, inches	30
Stand pipe, diameter, inches	6
thickness, inch	1
Supply pipe, diameter, inches	1½
Compressed air chamber, diameter, outside, inches	27
thickness, steel, inch	½
length, feet	5
supply, diameter, inches	2
Air compressor, diameter, outside, inches	12
thickness, inch	.23
length, feet and inches	10–8½
Supply valve, diameter, inches	2½
Discharge valve, diameter, inches	2

Electric Plant.—There are three generating sets made by the General Electric Company, Schenectady, N. Y. The dynamos are 24 kilo-watt multipolar and have each, at 400 revolutions, an output of 300 ampères at 80 volts. Each set is driven by a vertical compound engine, with cylinders 8½ and 13 inches in diameter by 8 inches stroke, directly coupled to armature shaft. The bed plate is common to both engine and dynamo and occupies a floor space of 8 feet 2⅛ inches by 31 inches. The com-




U. S. Battle Ship 'Oregon',
525 Gallon Hydraulic Pump.
Scale
Section through Valve.
Full size.
24"
18"
6"
12"
25¾"
15¾"
15"
2'-11"
18"


60"
Test Pressure
Working Pressu
Air Compressor
Test Pressure = 300 lbs. pe
Working Pressure = 150 lbs. pe


W. iron tube 12" dia galvanized.
Pressure of Water Ports = 2500 lbs. per sq. inch.
Pressure of Water Ports = 600 lbs. per sq. inch.
12
12½
55
Head.

Accumulator for Hydraulic Pump.
U. S. S. 'Oregon.'

bined weight of generator, engine and bed plate is about 9,000 pounds.

Outlets for 166 10 c. p., 422 16 c. p. and 18 32 c. p. lights, a total of 606, are distributed as follow:

Bracket lights,	9 single.
Deck lights,	67 "
Portable hand lamps,	94 "
Bulkhead lights,	51 "
Coal bunker lights,	86 "
Ceiling ring lamps No. 1,	16 "
Ceiling ring lamps No. 2,	68 "
Steam tight globes,	56 "
Desk lights,	38 "
Magazine lights (30 standard and 8 special),	38 double.
Signal lights (4 double and 11 single),	15
Truck lights,	1 double.
Side lights,	2 double.
Mast head and towing,	2 double.
Cargo reflectors,	4 quadruple.

There are four 25,000 candle-power search lights, 60 centimeters in diameter, made by Messrs. Sauter, Harle & Co., Paris; two of these are on top of pilot house and two on stands at after end of bridge. The lamps are vertical, hand or automatic, and are designed for an 80 ampère current at about 50 volts. For signaling there are four double lanterns, with cable connection and keyboard, admitting of thirty combinations being made. Each half of each double lantern is fitted with a fresnel lens, the upper one being red. There is one standard Navy switchboard complete, with all connections, switches, cutouts, &c., necessary for the four search lights, three motor and nine incandescent circuits, and one pressure board, ground detector and measuring instruments. The pressure board has points connecting the volt meter with the terminals of each dynamo, and separate volt meters for each search light circuit. On the bulkhead forward of the cabin, there are annunciators connecting with the water alarms in each

bilge compartment and with the thermostats in the coal bunkers and paint room.

For ventilating the dynamo room, there are two stationary fans, arranged for forcing air into the room. Each fan is driven by a 2-H.P. electric shunt motor at a speed of 1,570 revolutions, and has a capacity of 2,200 cubic feet of air per minute. For exhausting air from the double bottom, &c., there are four portable fans, each driven by a ¼-H.P. electric series motor at 1,863 revolutions, and having a capacity of 400 cubic feet per minute.

In the 8-inch turrets there are four 9-H.P. electric motors for hoisting ammunition.

Watts:

3 300 ampère generators		72,000
606 lights (10, 16 and 32 candle power)	34,619.2	
4 search lights	25,600	
Signaling apparatus	547.2	
2 2-H.P. motors	2,984	
4 ¼-H.P. motors	746	
4 9-H.P. motors	25,600	
Control stand, search light	3,200	
		93,296.4

NUMBER OF ENGINES ON BOARD.

Engines	*Steam and water cylinders.*
2 Main engines,	6
2 Main air pumps,	4
2 Main circulating pumps,	4
2 Auxiliary air and circulating pumps,	2
2 Hot well pumps,	2
4 Fire and bilge pumps,	4
2 Water service pumps,	2
2 Reversing engines,	2
2 Turning engines,	4
2 Hydraulic steering gear pumps,	4
4 Hydraulic pumps for 13-inch turrets,	4
2 Ventilating blowers in engine room,	4
4 Ventilating blowers on berth deck,	8
9 Forced draft blowers,	18
4 Main feed pumps, main boilers,	4

Engines.		*Steam and water cylinders.*
4	Auxiliary feed pumps, main boilers,	4
1	Main feed pump, auxiliary boilers,	1
1	Auxiliary feed pump, auxiliary boilers,	1
3	Dynamo engines,	6
4	Ash hoist engines,	8
1	Engineer's work shop engine,	1
2	Evaporator and distiller pumps,	2
1	Fresh water pump,	1
1	Sanitary pump,	1
4	8-inch turret engines,	8
2	13-inch turret engines, hydraulic,	6
1	Ice machine,	1
2	Air compressors for torpedo tubes,	4
1	Windlass,	2
5	Winches,	10
2	Boat cranes,	4
2	Propelling engines, steam cutter and launch,	4
2	Feed pumps for same,	2
84		138

The following are some of the more important weights, given in pounds:

Propellers (one), 3 blades	10,466
1 hub	8,860
42 securing studs and nuts for blades	1,974
cone piece, cover plates and cap bolts	528
Shafting, one engine.—1 propeller shaft, complete	17,113
1 line shaft, 2 sections	17,034
1 line shaft casing	4,465
1 thrust shaft	9,409
1 crank shaft, 3 sections	18,732
36 bolts and nuts	450
Reciprocating parts.—1 H.P. piston, complete	1,111
1 I.P. piston, complete	1,796
1 L.P. piston, complete	3,577
1 crosshead, complete	1,323
1 piston rod, complete	1,136
1 connecting rod, complete	4,079

		H.P.		*I.P.*		*L.P.*
Cylinder casing		11,090		14,492		25,177
Cylinder liners		1,848		3,010		4,524
Valve chest liners	(2)	400	(4)	800	(8)	1,600
Cylinder covers		1,335		2,155		4,375
Valve chest bonnet, top		276	(2)	556	(4)	1,112
bottom		223	(4)	446	(4)	844
Piston valve complete with balance piston and valve steam	(1)	591	(2)	1,385	(4)	2,817
Y-frame (1)						6,638
Bed plate, 3 sections						20,229
Main bearing brasses (6)						6,385
Front columns (3)						3,456
Main condenser (1)						23,307
Auxiliary condenser (1)						2,580
Main circulating engine						2,015
Main circulating pump						3,441
Main air pump						13,249
Main boiler without fittings						121,973
Fittings for one main boiler						28,032
Forward smoke pipe, auxiliary smoke pipe and uptake above protective deck						25,434
After smoke pipe and uptake above protective deck						22,309
Breeching for one main boiler up to protective deck						18,012
Auxiliary boiler without fittings						30,788
Fittings for one auxiliary boiler						7,571
Breeching and uptake up to main smoke pipe						3,541
Water for one main boiler, 6 inches above tops of combustion chambers						75,900
Water for one auxiliary boiler, 6 inches above tops of combustion chambers,						18,690

Preparatory to the official trial, the *Oregon* was docked at Hunter's Point on April 23, 1896, when her bottom was cleaned, painted and tallowed, and the pitch of the propeller blades changed from 16 feet to 15 feet 6 inches. She was taken out of dock on April 30, 1896, and prepared as rapidly as possible for the trial.

The contractors' engineer force was as follows: 1 chief engineer, in charge of all machinery, in engine rooms; 1 chief engineer in fire rooms; 4 engineers; 16 oilers; 16 machinists; 4 storekeepers and 4 wipers in engine rooms; 37 firemen; 37 coal passers; 8 water tenders (machinists); 16 oilers (one of whom was a boilermaker) and 11 machinists and 4 helpers in the deck department, making a total of 161 men.

During the forenoon of May 9, 1896, the *Oregon* left San Francisco for Santa Barbara, the main boilers only being used. From the time the ship passed the Heads, about 9·25 A. M., up to midnight, the average steam pressure was 145 pounds, and the revolutions, 95 per minute. From midnight up to 6·20 A. M., May 10, the engines were run at about 40 revolutions per minute. The revolutions were then increased and preparations made for giving the ship a trial run over the course from the western range to her anchorage off Santa Barbara, where she arrived about 10 A. M. During this run, with the main boilers only, the highest number of revolutions was 129 and the average number, 125; the steam pressure, about 140 pounds; and the speed, at the rate of 16.35 knots. During the remainder of the day and the following Monday, preparations were made for the official trial which was to take place on Tuesday, May 13. On this date anchor was weighed about 6·20 A. M., and the ship proceeded towards the west end of the course to ascertain the force of the swell and wind in the channel. The conditions not being favorable, the ship returned to her anchorage off Santa Barbara to await more favorable weather.

OFFICIAL SPEED TRIAL.

The official speed trial was made on May 14, 1896, and consisted of a run each way over a measured distance of 31.08639 nautical miles. The first run, westward, was made at the rate of 17.08 knots, and the second run, eastward, at the rate of 16.49 knots, the average of the two runs being 16.78 knots; a tidal correction of 0.011 knots in favor of the ship increased the average for the two runs to 16.791 knots. Before reaching the end of the west range, the head wind was very fresh and the swell became a moderate sea; after running a mile or more to the westward of the range, the swell became a heavy sea.

All boilers were used during the trial, but the main boilers only were used under forced draft. Excepting that used by the steering gear pumps and dynamos, all the steam generated was used by the main engines and auxiliaries. Steam was made readily and no disposition to prime was manifested. The work-

ing of the main engines was highly satisfactory and unaccompanied by vibration. The after main journal of the starboard engine warmed up slightly early in the first run, but was soon cooled with water, and continued cool throughout the remainder of the trial. As a precautionary measure, a light spray was also turned on the crank pins. The auxiliaries worked well and required no special attention.

Immediately after the trial, the ship was manœuvred in turning, etc., and returned to the anchorage off Santa Barbara about 2·30 P. M. At 3·15 P. M., the *Oregon* departed for San Francisco, carrying steam at 145 pounds on all boilers, and the engines making 98 revolutions. Owing to a heavy northwest wind and sea, which gave the Trial Board an opportunity to judge of the seagoing qualities of the ship, the engines were slowed, at 9 P. M., to 70 revolutions per minute. After a short stay in Santa Cruz, the vessel arrived off the Union Iron Works, San Francisco, at 1 P. M., May 16.

After the ship's return to San Francisco, the machinery and boilers were opened and carefully examined, and all found in good condition, with a few slight exceptions.

The 13-inch turret machinery was tested, and after some minor changes, was operated successfully. The 8-inch turret machinery was also tested and performed in a satisfactory manner.

DATA OF OFFICIAL TRIAL.

Draught, mean for trial, forward, feet	24
aft, feet	24
Displacement at mean draught, tons	10,250
Area of immersed midship section, square feet	1,534
Wetted surface, square feet	28,890
I.H.P. (total) per 100 square feet of wetted surface	37·57
Same at 10 knots, reduced in ratio of 3·5 power	5.786
Average speed, in knots	16.791
Slip, mean of both screws, per cent	14.33
$\text{Speed}^3 \times$ Area of immersed midship section $\div$ I.H.P.	668.8
$\text{Speed}^3 \times \text{Displacement}^{\frac{2}{3}} \div$ I.H.P.	204.96

SYNOPSIS OF STEAM LOG.

	Starboard.	*Port.*
Steam pressure, boilers, per gauge, pounds per square inch	162.8	
engines, per gauge, pounds per square inch	156.5	155.91

	Starboard.	*Port.*
Steam pressure, first receiver, absolute, pounds per square inch..	82.125	82.24
second receiver, absolute, pounds, per square inch	35.312	36.11
Vacuum, inches of mercury	24.69	25.28
Throttle	Wide open.	
Revolutions, per minute	128.289	128.208
Mean pressure H.P. cylinder	59.60	60.794
I.P. cylinder	31 55	32.606
L.P. cylinder	18.661	21.2152
equivalent, reduced to L.P	44.193	47.434
Cut off for all cylinders from beginning of stroke	.7	
Air pressure in fire rooms, inches of water	.99	
Revolutions per minute, blowers in main fire rooms	295	
engine rooms	370	
air pumps, main	160.82	162 5
circulating pumps, main	291.3	238.12
Double strokes per minute, hot well pump	45	
water service pump	36	
feed pumps	21.846	

INDICATED HORSE POWER.

Main engines, H.P	1,484.16	1,512.60
I.P	1,536.05	1,586.83
L.P	2,233.50	2,537.18
Total	5,253.71	5,636.61
Total for both engines	10,890.32	
Air pumps	8.771	7.735
Circulating pumps	51.478	34.467
Feed pumps	44.354	
Other auxiliaries	73.9	
Collective I.H.P. of all auxiliaries	220.705	
main engines, air, circulating and feed pumps	11,037.125	
all machinery in operation during trial	11,111.025	
all machinery, during trial, per square foot of G.S	18.037	
all machinery, during trial, per square foot of H.S	.573	
main engines, air and circulating and feed pumps, per square foot G S	17.917	
main engines, air and circulating and feed pumps, per square foot H.S	.569	

COAL.

Pounds per hour	23,593.5
per I.H.P., collective, all machinery in operation	2.123
main engines, air, circulating and feed pumps	2.137
per square foot of G.S.	38.30
H.S.	1.216
Cooling surface, square feet per I.H.P.	1.224
Heating surface, square feet per I.H.P.	1.745

The coal used on the trial was Welsh, Harris Deep Navigation, selected, put up in 98 pound bags, which were tallied off as used.

At the end of the trial, the tallies were counted in the main fire rooms, and the bags counted in the auxiliary fire room.

-5
123

137
30
216
224
745

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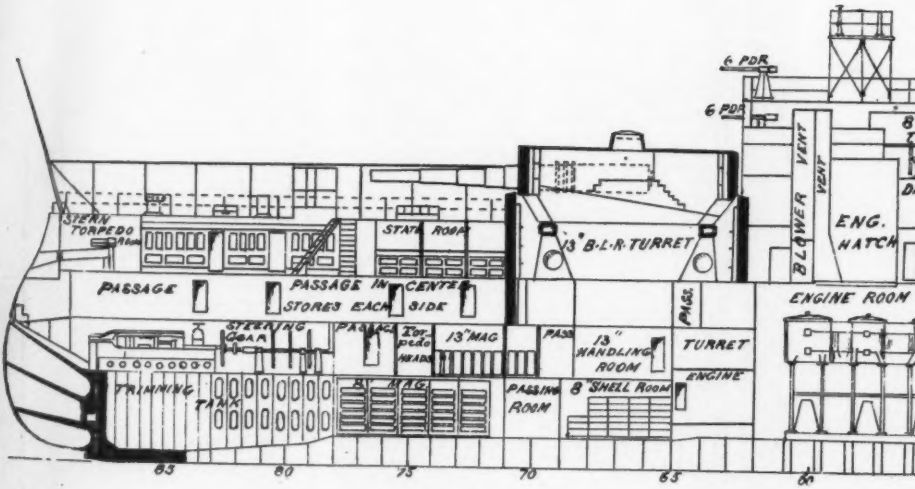
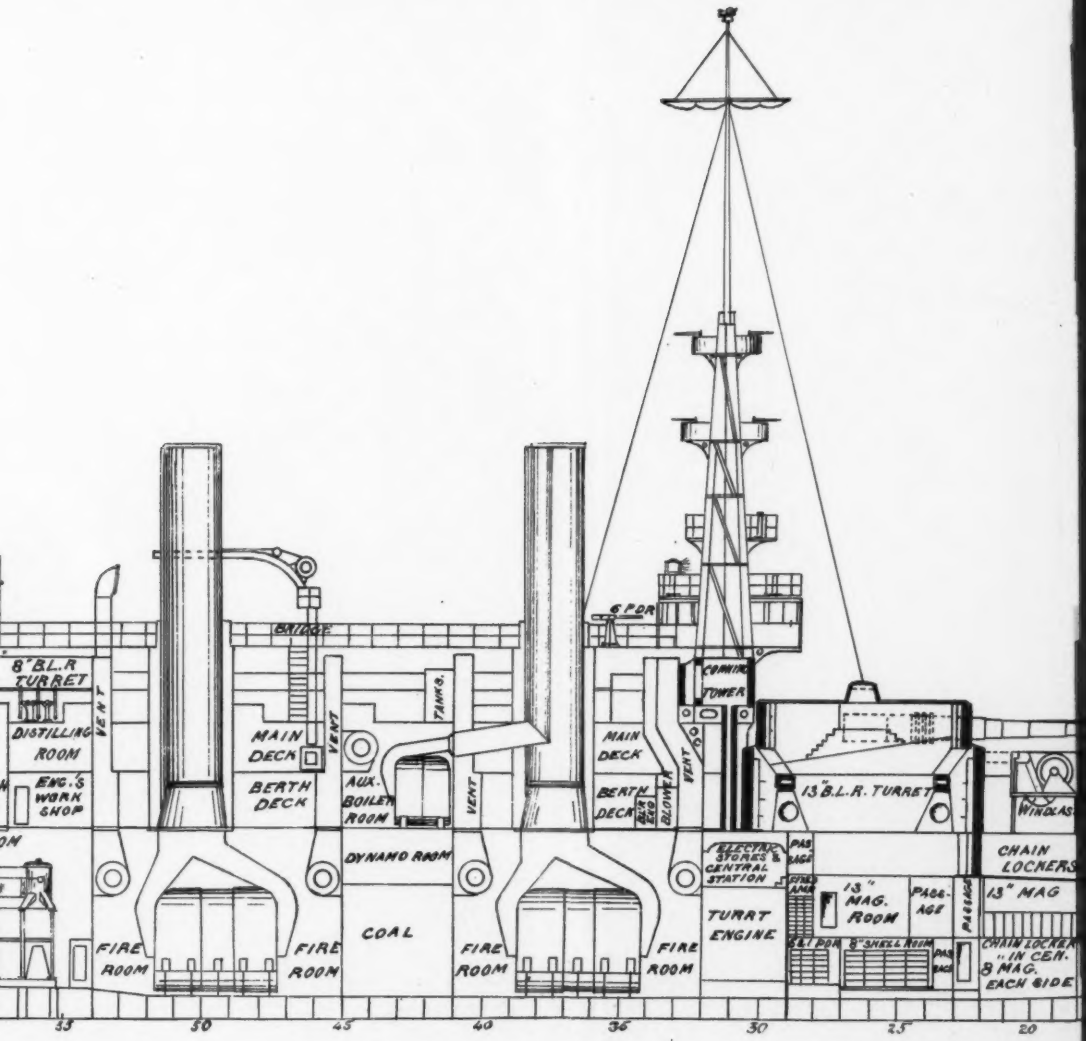

6 PDR.
6 PDR.
BLOWER VENT
VENT
ENG. HATCH
STERN TORPEDO Room
STATE ROOM
13" B.L.R. TURRET
PASSAGE
PASSAGE IN CENTER
STORES EACH SIDE
ENGINE ROOM
STEERING GEAR
PASSAGE
Torpedo HEADS
13" MAG.
PASS.
13" HANDLING ROOM
TURRET
ENGINE
TRIMMING TANK
8" MAG.
PASSING ROOM
8" SHELL ROOM
85
80
75
70
65
60


8" B.L.R. TURRET
DISTILLING ROOM
ENG.'S WORK SHOP
VENT
BRIDGE
MAIN DECK
BERTH DECK
VENT
AUX. BOILER ROOM
TANKS
VENT
DYNAMO ROOM
COAL
FIRE ROOM
FIRE ROOM
FIRE ROOM
FIRE ROOM
6 P.DR
MAIN DECK
BERTH DECK
BKR ENG
BLOWER
VENT
COMING TOWER
ELECTRIC STORES & CENTRAL STATION
PASSAGE
13" B.L.R. TURRET
13" MAG. ROOM
PASSAGE
TURRET ENGINE
S.L.P DR
8" SHELL ROOM
PASSAGE
WINDLASS
CHAIN LOCKERS
13" MAG
PASSAGE
CHAIN LOCKERS "IN CEN." 8 MAG. EACH SIDE
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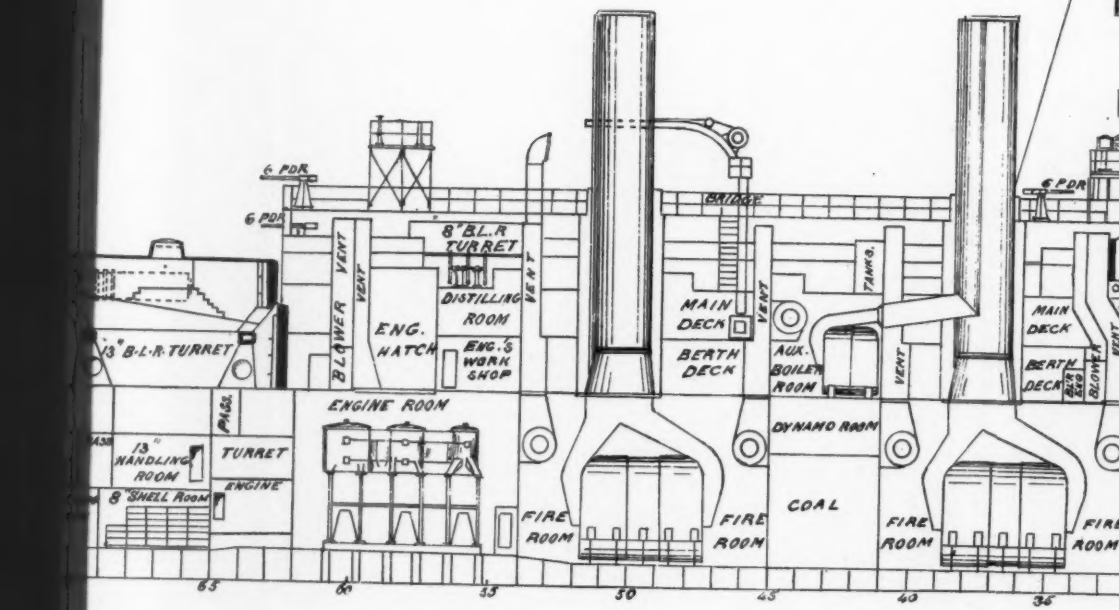
6 PDR.
6 PDR.
8" BL.R TURRET
BRIDGE
6 PDR.
BLOWER VENT
VENT
ENG. HATCH
DISTILLING ROOM
ENG.'S WORK SHOP
VENT
MAIN DECK
BERTH DECK
VENT
AUX. BOILER ROOM
TANKS
VENT
MAIN DECK
BERTH DECK
13" B.L.R. TURRET
PASS.
13" HANDLING ROOM
TURRET
8" SHELL ROOM
ENGINE
ENGINE ROOM
DYNAMO ROOM
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FIRE ROOM
COAL
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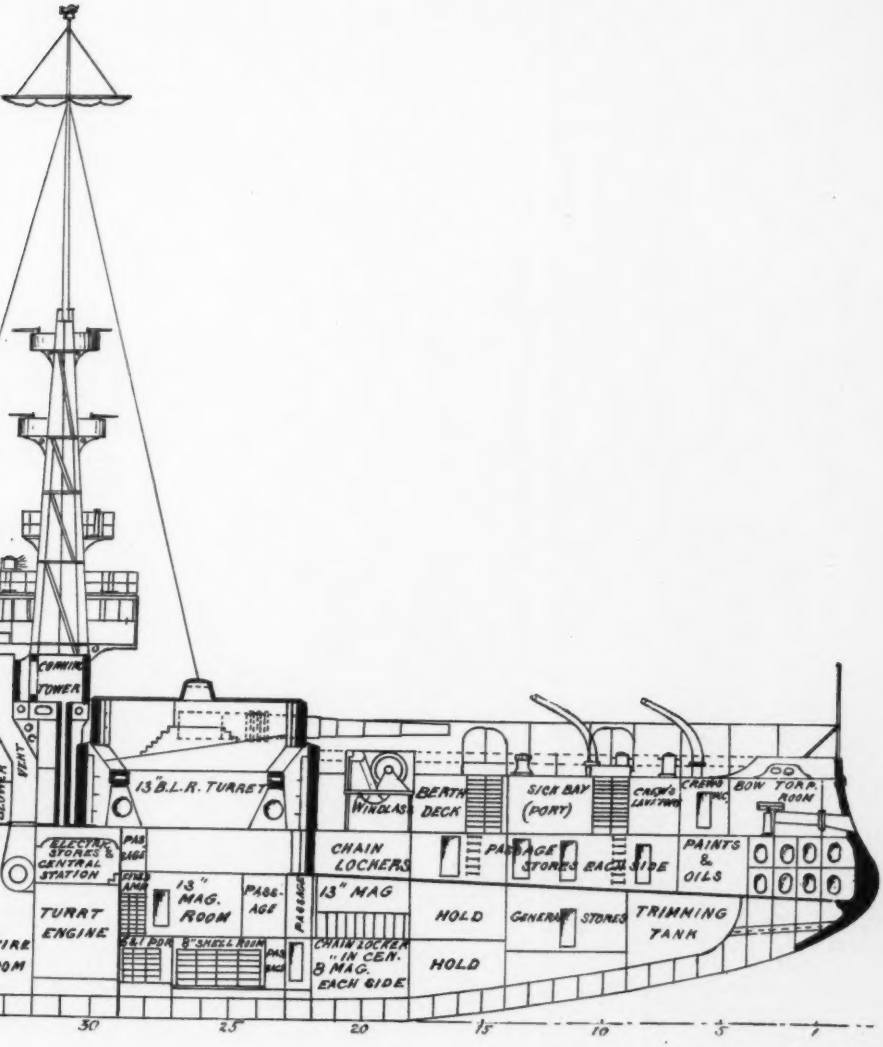
CONNING TOWER
13"B.L.R. TURRET
WINDLASS
BERTH DECK
SICK BAY (PORT)
CREWS LAVATORY
CREWS W.C.
BOW TORP. ROOM
ELECTRIC STORES & CENTRAL STATION
PASSAGE
CHAIN LOCKERS
PASSAGE
STORES EACH SIDE
PAINTS & OILS
TURRET ENGINE
13" MAG. ROOM
PASSAGE
13" MAG
HOLD
GENERAL STORES
TRIMMING TANK
CHAIN LOCKER "IN CEN. 8 MAG. EACH SIDE
HOLD
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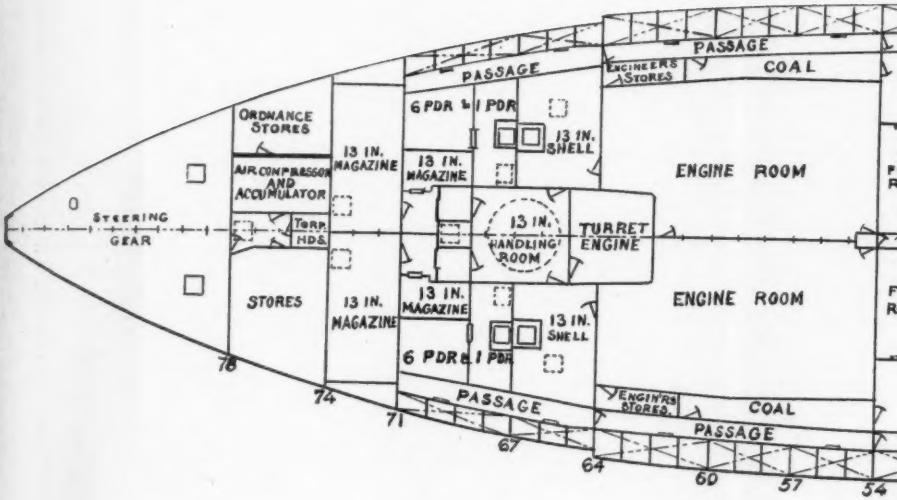
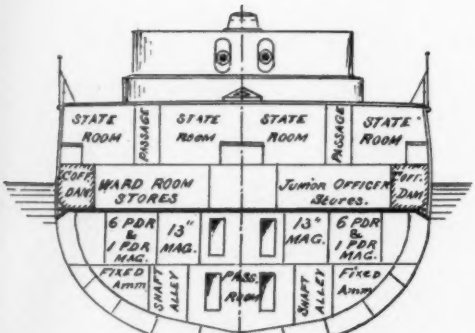
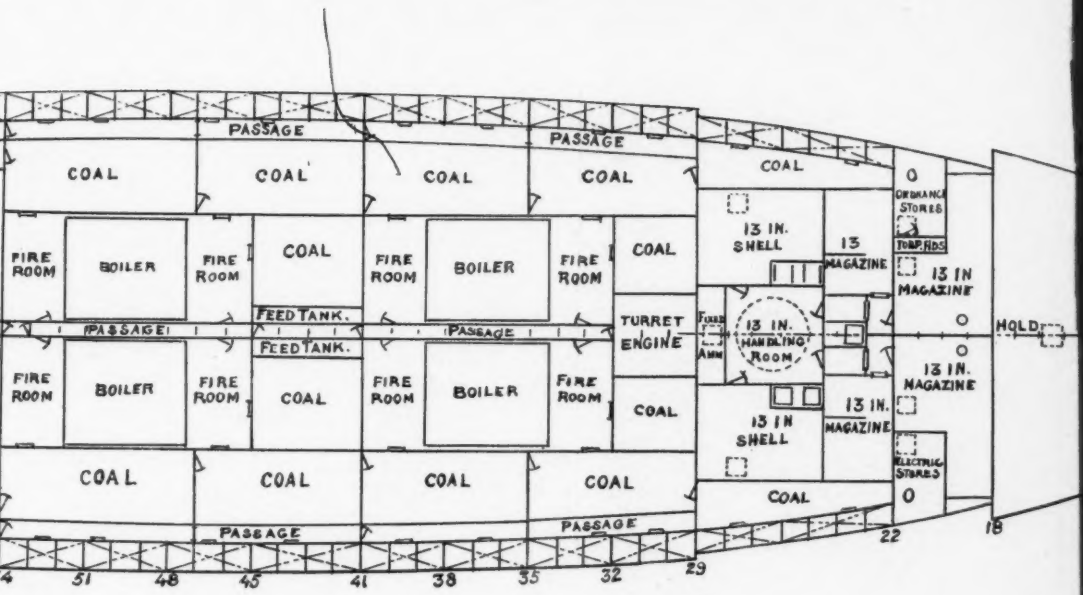
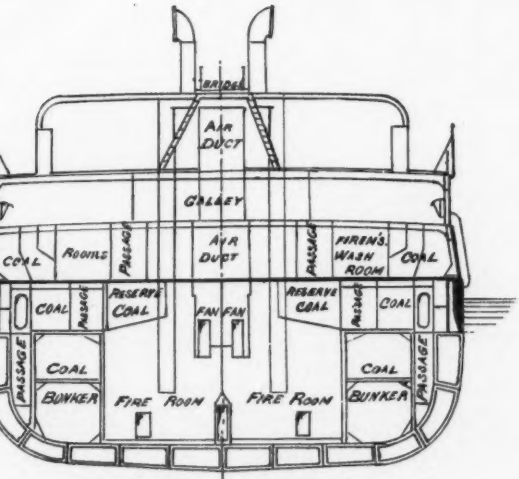
1



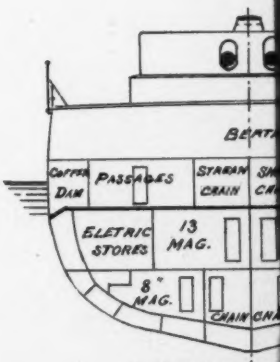


SECTION AT FRAME 71.





MIDSHIP SECTION.



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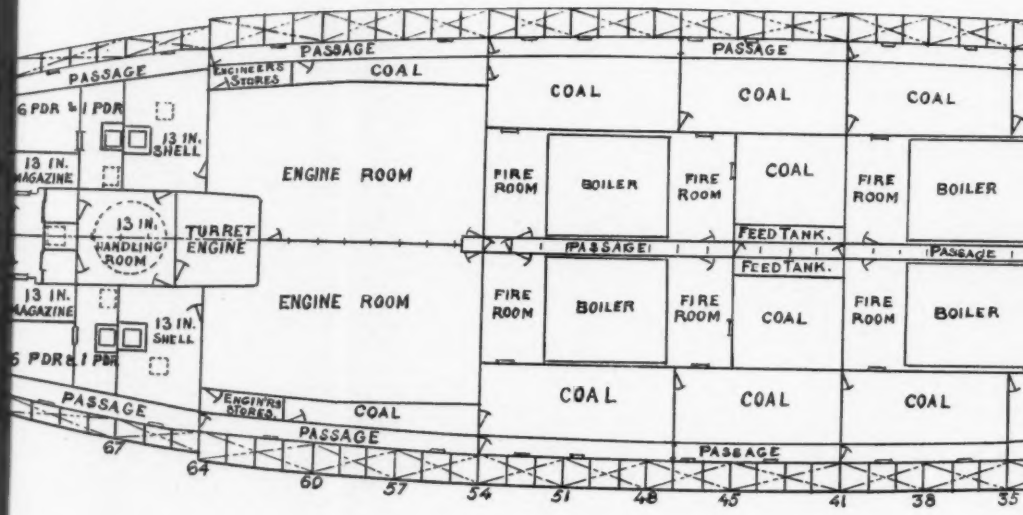
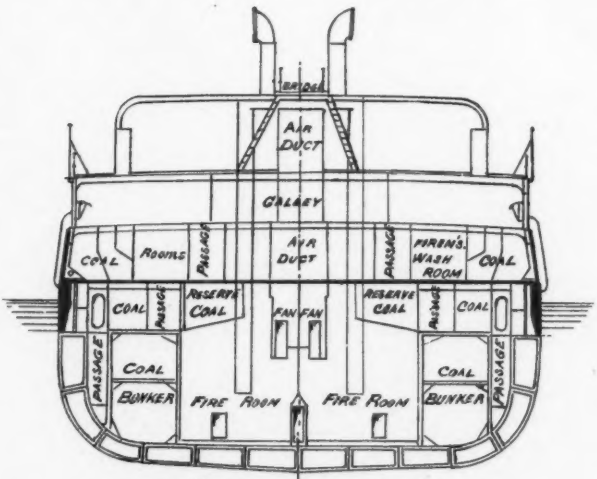
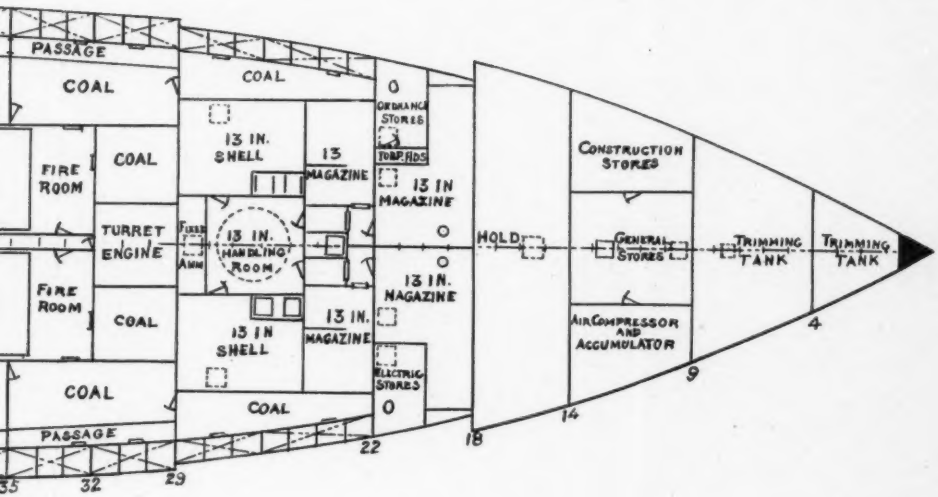
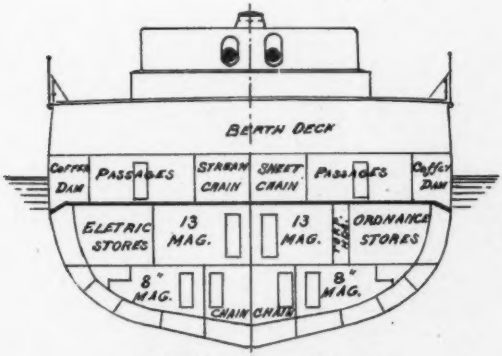




MIDSHIP SECTION.





SECTION AT FRAME 22.

COMPOUND MARINE BOILERS.

By Colonel N. Soliani, Director of Naval Construction, Royal Italian Navy; Member.

[Read at the Thirty-Seventh Session of the Institute of Naval Architects, March 26, 1896.]

The steady advance of water-tube boilers in the field of steam navigation has aroused a natural reaction in favor of ordinary marine cylindrical boilers, which, according to many, although inferior in certain respects, possess features of great value for marine purposes, not yet fully secured in the new boilers. This view refers, however, to boilers for ships other than torpedo craft, which have requirements that only water-tube boilers can now fulfill. Within these limits the contention in favor of cylindrical boilers does not appear groundless.

In fact, the marine cylindrical boiler is not a new production of the inventive genius of man, but is the result of experience of two generations at sea. It is the last stage reached of development and improvement, under existing practical conditions, of an "organ" in the evolution of the entire "organism," "the steamship," to which it belongs. And, in such a long adaptation to surrounding conditions, the marine boiler, from the early types to the present one, has, in effect, developed features of real fitness for ocean navigation, and reached a state of perfection not easy to attain immediately with any new boiler.

The prominent features of the modern marine cylindrical boilers are well known, viz., efficiency, simplicity of parts, fewness of bolted joints, durability, easiness of inside inspection, fitness to available space on board ships, small liability to derangement, possible concentration of large power in few boilers, so reducing number and complication of pipes and fittings, steadiness of action by which water feed and steam pressure are under easy control, facility of repair of the heating tubes under steam,

adaptability for temporary use of sea water for supplementary feed, &c.

Although some of the foregoing characteristics may be claimed also for water-tube boilers of various types, others of them are certainly special to the cylindrical boiler, and it is to these important features that cylindrical boilers owe their success in the domain of ocean navigation and the present campaign in their favor.

In this respect it is worth notice that, if we except France, where water tube boilers of the Belleville and a few other types are in general use, both for merchant and war ships, in England and other countries the Mercantile Marine has not yet shown any marked propensity to abandon its familiar and faithful servant; while the Navies, although now in full swing for the new boilers, began really to feel the want of a change, only when the cylindrical boilers "appeared" unsuitable to forced draft. I use on purpose the word "appeared," because I think it is not yet proved whether the proclaimed unsuitableness is unavoidably due to organic constitution of the boilers, or to the magnitude of the extra strain and suddenness with which it was applied before the boilers were given time to adapt themselves to the new demands made upon them.

In support of this view, the very good results obtained with the Serve tubes, and with the Howden and Brown systems of combustion, by which the steaming power of marine cylindrical boilers, per unit area of wetted heating surface, has been brought up to the limits which were lately deemed dangerous, might be mentioned; but, apart from these arrangements, which, if efficient in increasing the specific power of the boilers, have certainly not improved them in respect of lightness and suitableness to rapid steaming—which are prominent features of the water-tube boilers—it may be asked: Have cylindrical boilers reached their last stage of development? Cannot such boilers compete much longer, or must they soon give way to the new comers?

Well, while it is pretty certain that, owing to certain important advantages which water-tube boilers offer, principally for Navy purposes, the difficulties which still beset their general adoption

will be vigorously attacked and finally overcome, I think, from what has been said above, that cylindrical boilers not only have, as yet, a great power of endurance in the mercantile competition, but that there is still room on their side for further improvement, by which their vitality may be increased and the struggle prolonged, even for Navy purposes, with advantage to the great interests involved.

This new vitality may, I think, be conferred on cylindrical boilers by "compounding" them with water tubes in such a way as to make them partake, to a certain extent, of the good features of the water-tube boilers, without detracting much from their own valuable characteristics.

There are already in the market various compound boilers, viz., boilers having the heating surface made up both of water and fire tubes. Such are the Roger's boiler, the Barthlet's boiler, the Anderson and Lyall's boiler, etc.; but none of them, as far as I know, may be styled "a real compound marine cylindrical boiler." Even the Anderson and Lyall's boiler, although more akin to it, is altogether a different thing; it is a special boiler of itself, having features which belong to various types, resembling a locomotive boiler in its furnace, a marine boiler in its combustion chamber, and a stationary boiler in its barrel.

In saying so I do not wish to disparage these boilers which, on the contrary, appear very good and efficient, but simply to show that they are not the kind of boiler I mean, viz., a marine cylindrical boiler compounded with water tubes to the extent that is necessary to give protection to the tubes and tube plates and improve the boiler also in other respects (such as economy of weight, fitness to rapid changes of temperature, &c.), but without altering its main characters. Such a result may, in my opinion, be achieved simply by doing away altogether with the water spaces around the ordinary combustion chambers and substituting for them water tubes, some of which would be properly arranged as a protecting screen in front of the tubes and tube plates.

My meaning will perhaps be clearer by reference to Figs. 1 and 2, in which the proposed alteration is sketched as applied both to single and double ended cylindrical boilers.

Such boilers, if successful, would be lighter, simpler, less sensitive to difference of temperature and to rapid changes of fire; while the screen of water tubes in front of the tube plates would in them, as in the Anderson and Lyall boiler, protect to a great extent plates and tubes from damage under forced draft. In other words, these boilers would fulfill most of the requirements of modern steaming at sea, and exert, if adopted, a useful function in the present period of transition, which, by them, would become longer and smoother. The benefit would be mainly felt by the Mercantile Marine, on account of the larger interests involved, and because of its requirements to which the ordinary marine boilers appear on the whole so well suited. Another advantage of the arrangement I propose would be the facility of admitting air under the back end of the fire grate, in a proper measure, to improve the efficiency of combustion, through a regulating door fitted under the bridge and underneath the casing of water tubes forming the combustion chambers.

In marine engineering I am only a *dilettante*, therefore in what I have had the honor to say, my aim has been simply to raise a question which seems important and to merit discussion by the experienced members of the Institution. My suggestions may be briefly summarized as follows, with a view to meet discussion:—

(1) For swift vessels, of small dimensions, designed for the use of torpedoes or special services, water-tube boilers are a necessity.

(2) For certain classes of warships of larger size, water-tube boilers are distinctly advantageous.

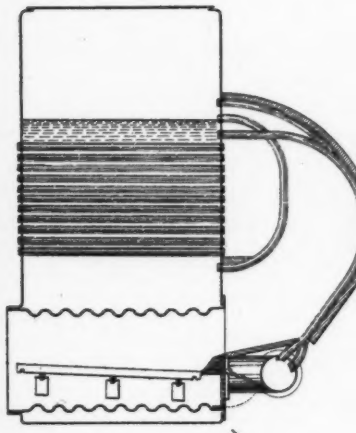
(3) For mercantile purposes and many classes of warships, the water-tube boilers are not yet perfectly suitable, and the cylindrical type of marine boiler is still to be preferred and its continued employment is probable for some considerable time.

(4) There is a possibility of retaining the most valuable characteristics of the cylindrical type, while securing increased efficiency and fitness to meet the exigencies of modern steaming, by means of arrangements of water tubes somewhat of the character illustrated by Figs. 1, 2 and 3.

COMPOUND

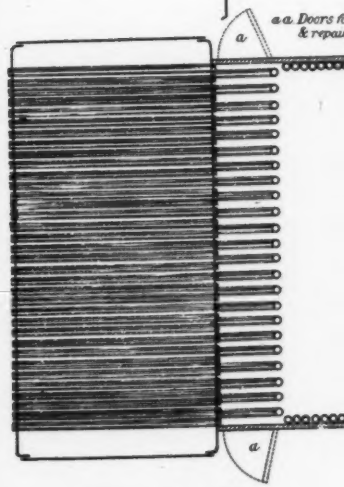
WITH CO

SINGLE ENDED



LONGITUDINAL VERTICAL SECTION

FIG. 1.

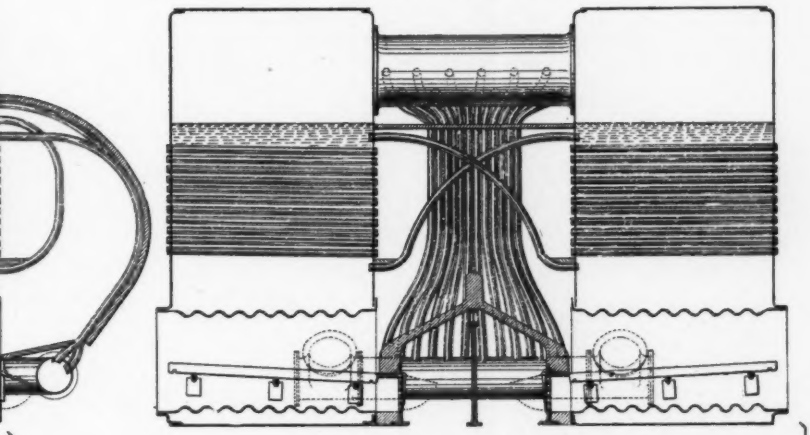


HORIZONTAL SECTION.

Compound Marine Cylindrical Boiler

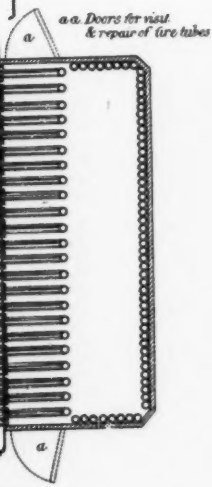
With Combustion Chamber Built up with Water Tubes.

Double Ended



Longitudinal Vertical Section.

Fig. 2.



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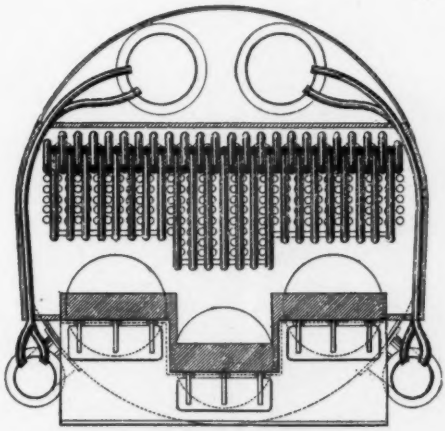
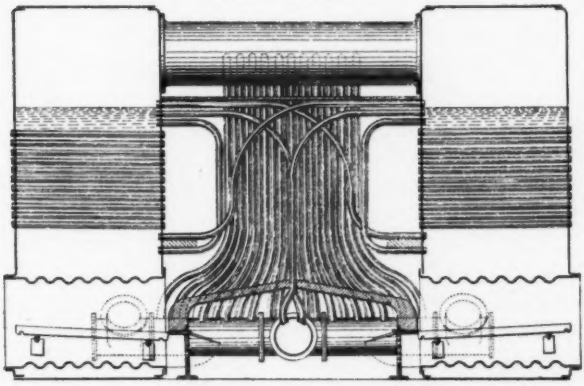


Transverse Vertical Section.

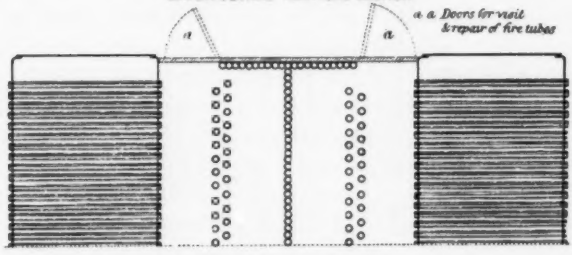
COMPOUND MARINE CYLINDRICAL BOILER

WITH COMBUSTION CHAMBER BUILT UP WITH WATER TUBES.

DOUBLE ENDED

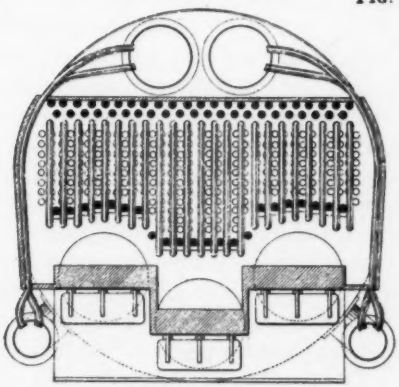


LONGITUDINAL VERTICAL SECTION



HORIZONTAL SECTION

FIG. 3.



TRANSVERSE VERTICAL SECTION

WATER-TUBE BOILERS.

By J. Watt, Esq., Associate.

[Read at the Thirty-seventh Session of the Institution of Naval Architects, March 26, 1896.]

Some years ago the writer had the honor of reading a paper on the subject of water-tube boilers before the Liverpool Polytechnic Society, and, after enumerating the points which constituted a good water-tube boiler, deduced therefrom the following rules or laws, which should be observed in designing a trustworthy steam generator. They were as follows:

(1) "The tubes should be arranged in a position to absorb the greatest amount of heat, by causing the flame to travel in an upward direction at right angles to their axis.

(2) "The tubes should be in a horizontal or inclined position, as the most efficient to emit heat.

(3) "The steam generated should have free and unobstructed escape to the steam receiver.

(4) "The circulation or supply of water to the tubes must be copious to prevent overheating.

"These are the theoretical, and form the essential, conditions of an efficient water-tube steam boiler.

"But, in addition to these, there is another not the less important which concerns the practical part or life of a boiler, viz., the facilities for inspection, cleaning and repairing."

It is twenty-two years since the above was written, and, although old, it is quite as applicable to-day as then; and, as far as the writer's experience goes, quite borne out by practice. There is, perhaps, no water-tube boiler made that will fully come up to all the requirements here laid down, but the nearer we can approach this standard, the more perfect and successful will be the

boiler; and by applying this standard to any existing boiler, we are enabled to point out, not only its merits, but also its defects.

It is not the writer's intention of going over the whole range of this subject of water-tube boilers, but to lay before you the result of a few experiments, which may elucidate and explain some of the many mysterious circumstances connected with this complex subject.

A water-tube boiler may be defined simply as an assemblage of tubes filled with water and placed over a fire. The ends of the tubes are fixed to two receivers, which combine the whole together. If the receivers be cylindrical where the tubes fit, then the tubes are more or less bent to suit; if flat, the tubes are generally straight. The advocates of bent tubes claim the bending as important in taking up or accommodating themselves to the expansion of the boiler when under steam. On the other hand, those who advocate the straight tubes find no difficulty arising from this point. Straight tubes offer the best advantages in respect of inspection, cleaning and renewals.

The experiments were made with a small model boiler (see Figs. 1 and 2) containing thirty-nine straight tubes, each three-eighths inch diameter by 9 inches long, containing 2.9 square feet of heating surface. The receivers to which the tubes were attached were flat, the end plates were of glass, so that the tubes could be seen right through, and the action going on inside could be distinctly observed. A steam receiver was also placed on the top, connecting the other two receivers. Heat was supplied by two Bunsen burners, consisting of two tubes with cross slots, the heating taking place being very much similar to that of an ordinary firegrate furnace. The model was so constructed that it could be used or tried in a great number of different positions.

The object of the first series of experiments was made with a view of finding out the relative value of heating surface when the tubes were angled from a horizontal position gradually to that of a vertical one, or through an angle of 90°. The experiments were conducted at atmospheric pressure, and commenced by first raising a given weight of water to the boiling point, and then

ascertaining the amount evaporated after an interval of fifteen minutes.

After a few preliminary trials it was found that when the boiler was angled about 10° from the horizontal the evaporation was highest, viz., 8½ oz.; when the angle was increased to 15°, the evaporation was 8¼ oz.; 30°, 7½ oz.; 45°, 6½ oz.; 60°, 5¾ oz.; 75°, 5½ oz.; and 90°, 5 oz. Again, on reducing the angle to 5°, the evaporation was 8¼ oz., and when level 7½ oz. It may be here stated that, owing to the pressure of gas varying a little, very seldom the same results could exactly be arrived at; but by making several trials the above is a fair average. This is graphically represented in Fig. 3 (top curve). The vertical ordinates representing the percentage of evaporation at the various angles at which the boiler was tried, beginning at the horizontal position and gradually rising to the vertical position. It was found when the boiler was angled 10° it gave the best result; therefore, 10° represents the maximum evaporation, or 100 per cent.

In looking at this diagram, we find that in any water-tube boiler whose tubes are inclined, say, 10°, by merely increasing the angle to 30°, the amount of water evaporated is reduced from 100 to 85, or 15 per cent. less. If the angle be increased to 60°, the decrease will be 33 per cent. And at 90°, or the tubes vertical, the reduction is a little over 40 per cent. This compares very favorably with the old-fashioned rule employed in the ordinary steam boiler, of allowing two square feet of vertical heating surface to be of equal value to each one of horizontal.

These experiments were conducted with the tubes placed in horizontal rows, so as to allow the products of combustion to travel in a zig-zag direction to the funnel. The next series were taken with the boiler turned on its side, so as to form the tubes into vertical rows, and giving the products of combustion a more direct course to the funnel (see Fig. 2A). The result is shown by the lower curve on Fig. 3. The highest percentage was 82 per cent. at 10°, and 53 per cent. at 90°, the best result showing a difference of 18 per cent. in favor of the former arrangement of tubes.

Instructive as these tests may be, the next series will show still

more striking results. In order to arrive at the duty performed by various tubes, or rows of tubes, and more especially those nearest to the source of heat. If we take another boiler—or, rather, a part of a boiler representing that row of tubes which is nearest to the fire—and place the two together, as represented in Fig. 4, we have the means of arriving at the evaporation of each boiler separately. This small boiler consists of six tubes only, having a heating surface of .44 square feet, compared with the larger one of 2.9 square feet, or a combined H.S. of 3.34 square feet.

The results of this arrangement are represented on diagram Fig. 5. The upper curve shows the combined evaporation of both boilers, and, although there is an augmented H.S. of about 15 per cent., yet there is very little difference in the amount evaporated. The lower curve shows the evaporation of the original or larger boiler, and we now see that at its best it is reduced from 100 per cent. to 40 per cent. at 10°, and from 60 per cent. to 17 per cent. at 90°. On the other hand, the small boiler is represented by the middle curve, and its evaporation at its best is 60 per cent. at 10°, and 45 per cent. at 90°. The above results may be stated in other words, viz.: That practically 60 per cent. of all the steam generated in any water-tube boiler with tubes at any angle is generated in the first or nearest row of tubes to the fire. The remaining 40 per cent. is left for the larger portion of the boiler to accomplish.

By reversing the positions of the two boilers—by placing the smaller on the top of the larger one—we can arrive at the evaporation of the top row; but this was found to be so small as not to be taken notice of. The writer had not the means of testing the intermediate rows; but the following table will not be very far off:

1st	row	nearest	to	the	fire	evaporated	60.0	per cent. of the total evaporation.
2d	"	"	"	"	24.0	"	"	"
3d	"	"	"	"	9.5	"	"	"
4th	"	"	"	"	3.5	"	"	"
5th	"	"	"	"	1.5	"	"	"
6th	"	"	"	"	1.0	"	"	"
7th	"	"	"	"	0.5	"	"	"
					100.0			

The importance of the above cannot be overlooked. Either the first row is doing too much or the back row too little; and the conclusion arrived at is that, practically, the first row is receiving the whole wear and tear of the boiler, therefore more liable to damage and renewals. This has proved itself in the case of copper tubes, which, although a better conductor of heat than either iron or steel, yet were unable to stand the severe work they had to perform. The danger from overheating and rupture is not only very unpleasant from a stokehole point of view, but the giving way at some critical moment, demands our most important consideration; in short, it is the vital part of the water-tube boiler.

Seeing this difficulty some time ago, the writer devised some means by which the first row was relieved of this heavy duty, and more laid on those immediately behind. This is accomplished by substituting tubes of much larger diameter nearest to the fire than those which are more remote. The larger tubes contain more water, and present less heating surface for the space occupied than those of smaller diameter. The result is that the evaporation is less with the larger tubes but greater with the smaller. Fig. 6 represents the arrangement. For the six $\frac{3}{8}$-inch tubes we now adopt three $\frac{3}{4}$-inch tubes in their place. The weight of water in the three tubes is double that in the six smaller ones, while the heating surface remains the same. The diagram representing the results of the trials is shown on Fig. 7. The top curve as before representing the results of the two boilers. Practically there is very little difference compared with the similar top curves of Figs. 3 and 5; if anything, it is slightly in favor of Fig. 7. But when we come to compare the two lower curves with the similar curves in Fig. 5, we find that they have almost changed places. Taking the top or larger boiler, the evaporation at 10° is nearly 60 per cent. of the total as compared with a little over 40 per cent. shown on the former trial. The curve dropping down at 90° to 27 per cent. against 17 per cent. Taking the lower boiler, representing the three large tubes, the evaporation is reduced from 60 per cent. to a little over 40 per cent. at 10° with the larger tubes, terminating at 38 per cent. at

90°. It will be observed that the two curves cross each other when the boiler is at an angle of about 55°, showing that the evaporation at this angle is about equal in each boiler. From this point on to 90° the smaller boiler evaporates more than the larger; but, as the angle decreases below 55°, the larger boiler evaporates more than the smaller. We here see that the evaporation in the first row of tubes is very much reduced, there is less liability to overheating, and accidents are reduced to a minimum.

The quantity of water evaporated by the first row of small tubes was at the rate of 5 pounds per square foot of H.S. per hour, and the velocity at the end of the tubes, about 3.8 feet per second. The tubes were full of semi-steam and water, so that no light could be seen at the other end; evidently these tubes were evaporating their maximum quantity with efficiency.

On the other hand, with the row of large bottom tubes, the rate of evaporation was about 3.5 lbs. per square foot H.S., and the velocity at the tube ends (steam only) about 2.9 feet per second. Up to an angle of about 60° a light could be distinctly seen through these tubes, the steam occupying about one third of the area on the top side, the water underneath presenting a clear, solid mass. Above 60° elevation the water and steam became more or less mixed up, so that a light could not be seen at the other end. From the apparently easy manner in which these tubes were doing their work, it was evident the maximum amount of evaporation had not been reached. There was a large reserve of solid water in the tube, and the steam appeared to pass freely away without taking any water along with it. Indeed, there could not be a strong water current, for on blocking up the bottom end of one tube to the extent of reducing its area to one fourth, there appeared to be no different result.

It must be remembered that the above trials were made at a pressure of one atmosphere where the relative volumes of steam and water are as 1,640 to 1. For higher pressures a corresponding rate of combustion may be adopted.

The most vital parts in any water-tube boiler, and the most easily damaged by overheating, are those tubes in close prox-

imity to the fire. To overcome this difficulty two courses are open, (*a*) by adopting small tubes and providing for a vigorous circulation; (*b*) by adopting larger tubes and a less active circulation. Adopting the former, there is a limit both in respect to the speed of the current and the quantity of steam in contact with the heating surfaces. According to Mr. Thornycroft's experiments, at a pressure of three atmospheres, the relative volume of steam and water passing through a number of $1\frac{1}{8}$-inch tubes was about 5.4 to 1, and at 12 atmospheres this would equal $1\frac{1}{2}$ to 1, or three volumes of steam, at an average, in each tube, to two of water. A condition of things which presents to us two evils, one is the danger arising from the tube becoming much hotter than the temperature due to the pressure. As an instance of this, there is the failure of copper tubes in water-tube boilers to stand this excessive heat. The second evil is the slow corrosion taking place, owing to part of the steam in contact with the tube becoming decomposed at a high temperature, forming oxide of iron and hydrogen gas. Some years ago apparatuses for superheating steam were placed in uptakes; but even at this low temperature their life was three or four years at the most.

By the improved arrangement of larger tubes to face the first and direct action of the fire, a larger body of more solid water is in actual contact with the heating surfaces. The liability to damage by overheating is reduced to a minimum; the duty of the various tubes more evenly distributed, and the steam generated more freely disengaged.

In conclusion, there is one point which, during the time these experiments were being made, confirmed the writer's views more strongly of a grave defect in Belleville water-tube boilers for marine purposes, and, as this boiler is now being freely adopted by our Admiralty, his humble protest must be taken from a tax payer's point of view.

Those who are responsible for the position and arrangement of this boiler on board of a sea-going vessel have evidently not given the subject of an unsteady platform any consideration. Numerous tubes have given way at sea; not that it is the only boiler that suffers from defective tubes; but in all probability

these same tubes would not have given way had the boiler not been tossed about in a sea way. In many instances these tubes have been replaced by thicker ones, and in some cases by Serve tubes, with little better results. Still the true cause of their failure is not discovered, therefore no effectual remedy applied, and thus the error is repeated.

The arrangement of all water-tube boilers, with horizontal or slightly inclined tubes on board ship, should be parallel with the line of keel. But it appears to be the rule, so far as this boiler in question is concerned, to place the same across the ship. Now, the inclination or angle of the Belleville boiler tubes is about 2° or 3° from the horizontal, and as 10°, say, is not an uncommon angle for a ship to roll at sea, it follows that the tubes will become depressed or angle reversed to the extent of 7° or 8°. A ship to roll from eight to ten rolls per minute is not uncommon, and therefore six or eight seconds would be the duration of one roll.

Now, imagine the ship rolling, a heavy fire on the grate, and in this time these lower tubes, generating, as we have seen, such a large volume of steam, which would immediately reverse the circulating current, fill the upper ends and be here imprisoned, only to be relieved by the next roll. The greater portion of the steam will now be transferred to the other end, to be again re-imprisoned, and so on till the ship gets into less turbulent waters.

With reference to what the continued effect on these semi-dry tubes would be in a sea-way, or in the event of the ship having a list, the result is left for your better and impartial judgment.

FIG. 1.

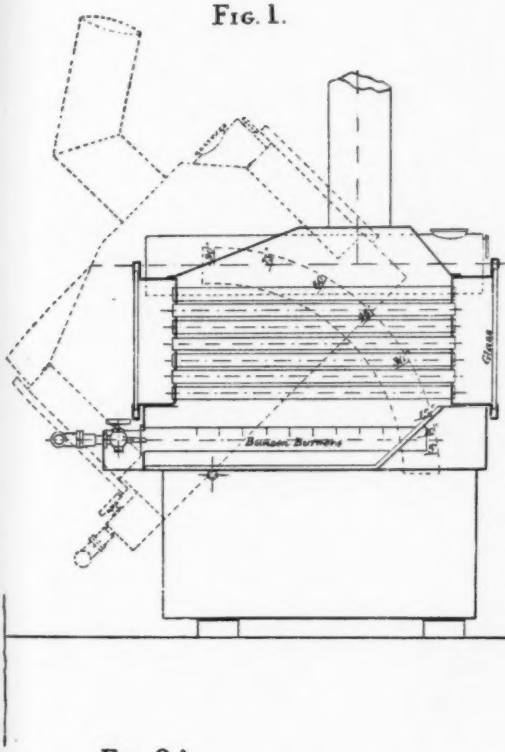


FIG. 2.

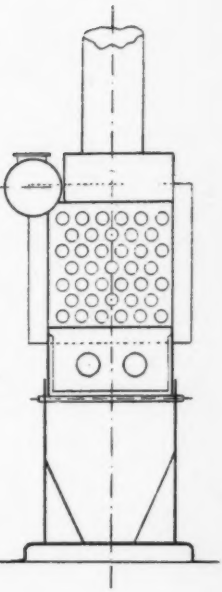


FIG. 2A

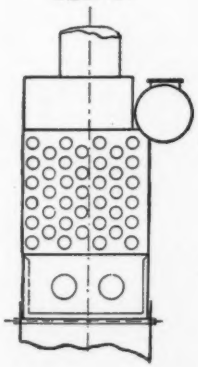
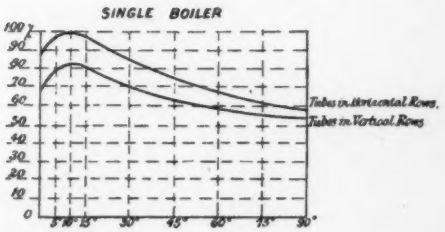


FIG. 3.



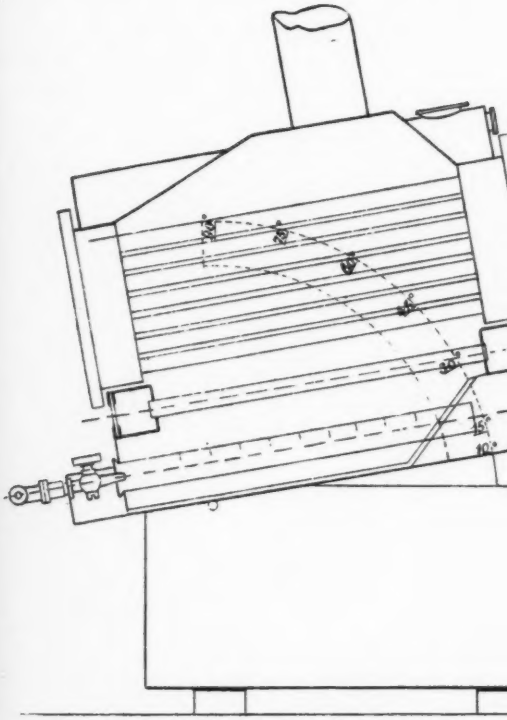


FIG. 5.

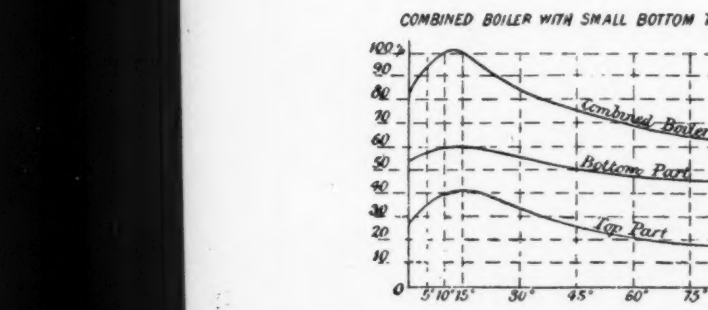
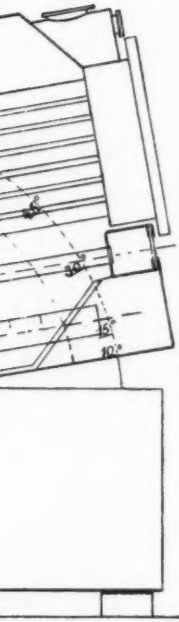

COMBINED BOILER WITH SMALL BOTTOM
100
90
80
70
60
50
40
30
20
10
0
Combined Boiler
Bottom Part
Top Part
5°
10°
15°
30°
45°
60°
75°

FIG. 4



5.

FIG. 6.

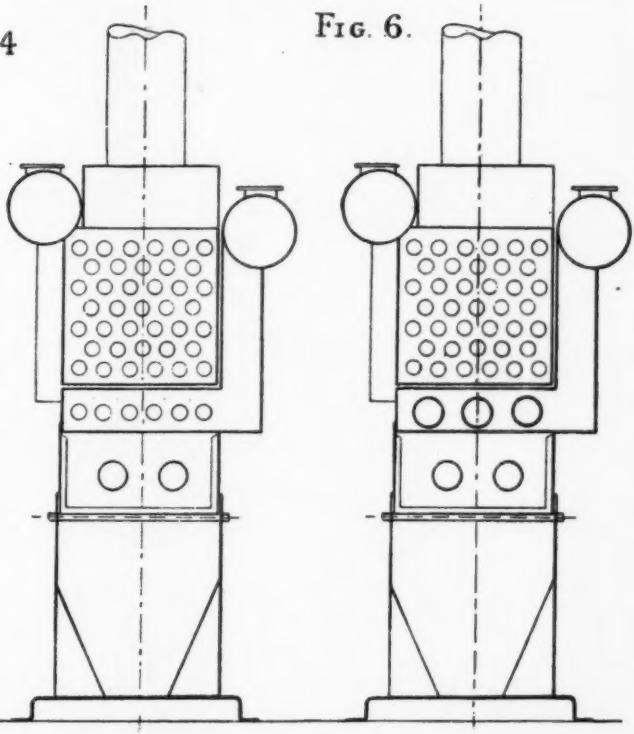
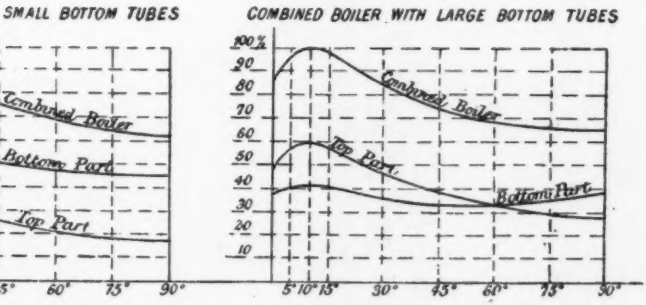


FIG. 7.



CIRCULATION IN WATER-TUBE BOILERS.

By Professor W. H. Watkinson.

[Read at the Thirty-seventh Session of the Institution of Naval Architects, March 26, 1896.]

The main object of this paper is to draw attention to a series of models, which will be shown in action at the meeting, and which I have had constructed in order to show the nature of the circulation in the various types of water-tube boilers. The tubes in these models are of glass, ranging in internal diameter from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inches, and the drums are provided with glass ends, so that the whole of the action in the boilers can be observed.

As there has been a great deal of discussion, and as inaccurate views are still prevalent regarding the causes of circulation in water-tube boilers, it will be well, before describing the action in the various models, to summarize the author's conclusions regarding this matter.

CAUSES OF CIRCULATION.

"The causes of circulation in water-tube boilers are:

"(1) The difference in density of the water due to difference in temperature when the fires are first lighted. This circulation is very sluggish.

"(2) When the water is all at approximately the same temperature, and steam is being generated, but not with sufficient rapidity to cause a break in the continuity of the water, a much more vigorous, but mainly local, circulation is set up by the entraining action of the bubbles of steam rising through the water.

"(3) When steam is generated with such rapidity, that in some part of the circuit there is steam or foam only present, a very rapid circulation takes place, due to the difference in density

between this steam or foam and the continuous water in the downcomers, internal or external."*

These conditions are illustrated by the annexed diagrams. In Fig. 1 steam is not being generated rapidly enough to completely fill any portion of the tube A with either steam or foam, and the continuity of the water in A being unbroken, the only cause of circulation, assuming the water to be all at the same temperature, is the entraining action of the bubbles rising through the water.

By many the circulation, in this case, is said to be due to the difference between the density of the column of water in B, and the average density of the steam and water in A. That this is not so is shown by the experiment illustrated in Fig. 2, in which air is sent into the inner tube from a horizontal nozzle at C. When the top of the inner tube is above the water level the rise of level in the inner tube is very small, and when the conditions are as shown the circulation is comparatively sluggish. If the nozzle C, however, be turned upwards a much better circulation is induced, but the action in this case is not analogous to that in a boiler.

Another way of regarding the matter is indicated in Fig. 3, where a series of beads are shown attached to a fine wire. When the beads are moved either upwards or downwards a circulation is set up due to their entraining action, exactly as in Fig. 1.

The circulation, therefore, under the conditions shown in Fig. 1 is due solely to entraining action, and not to difference in density of the substance in the two legs. It is due really to the difference in density between the steam and water in the same leg, which sets up a relative flow of the two, and the entraining action of the rising bubbles causes the circulation round the circuit, as well as local currents which are at the same time induced.

In Fig. 4 steam is being generated more rapidly, and portions of the tube are filled with steam to the complete exclusion of water from these portions. In this case a rapid circulation takes place on account of the average density of the substance in A

* From a paper by the author, Inst. Engineers and Shipbuilders in Scotland, January, 1895.

being less than that in B. This kind of circulation is by far the most thorough, as none of it is merely local.

When working at atmospheric pressure, at rates exceeding about 2 pounds of steam per square foot of heating surface per hour, and with tubes 1¼ inches in diameter, the bubbles do not fill up the whole diameter of the tube, as shown in Fig. 4, but the upper part of the tube becomes filled with foam to the complete exclusion of continuous water, as shown in Figs. 7, 8 and 10. The circulation in this case is, of course, due to the difference in density between the foam in tube A and the corresponding column of water in tube B, Fig. 10. The circulation in this case is also vigorous, but, as a considerable amount of water falls down from the foam, it is more local, and not as thorough as in the last case.

DESCRIPTION OF MODELS.

Model of Belleville Boiler (*Fig.* 5).—This consists of two elements, each containing 12 tubes of $\frac{5}{16}$-inch internal diameter joined in series. The distance between the centers of the end boxes is 2 feet 3 inches, and the inclination of the tubes is 4 per cent., as in actual boilers of this type. The action of the automatic non-return valve at A is very clearly shown. The normal level of the water is about that of the middle tube, but in starting in order to prevent overheating of the upper tubes it is necessary to have water in all the tubes.

The action in the Belleville boiler is so different from that in any other boiler that it may be well to explain it somewhat fully. As is well known, this boiler consists of a number of elements connected in parallel between the feed distributing box (as I prefer to call it) and the steam drum. The total length of tube in each element is roughly 150 feet, and, as the inclination is only 4 per cent., the upper end of this 150 feet of tubing is only 6 feet above that of the lower end, and the discharge into the drum takes place at about 1½ feet above this.

If each element consisted of one straight tube 150 feet long instead of twenty tubes connected by end boxes, as in the actual boiler, the circulation would be of the same nature as that in

other water-tube boilers, and a circulating force of, say, 1 pound per square inch (assuming the head effective for circulation to be two feet) might be great enough to push the water through the tubes, in spite of their great length. Owing, however, to the abrupt changes in the direction of flow of the water which take place at each junction box, the total resistance to the flow is too great to allow sufficient circulation with this circulating force.

To get over this difficulty, the orifices through which the water flows from the feed distributing box to the elements are very contracted, and at the bottom of each of the two downcomers is an automatic non-return valve. With these arrangements the action of the boiler is similar to that in the old-fashioned Savery steam pump; the water is forced into the elements intermittently by the available head of about two feet instead of by the atmosphere, as in Savery's pump, the non-return valve and the contracted orifices serve as the suction valve, the steam is generated in the tubes themselves instead of in a separate boiler, and the necessity of a delivery valve is got rid of by discharging into the steam drum above the water level.

The action, therefore, is intermittent, and some water is driven backwards through the contracted orifices during the time plugs of water and steam are being pushed forward into the steam drum. The non-return valves prevent water being driven back through the downcomers into the steam drum.

When warming up, the action is intermittent, as in all cases where the discharge takes place above the water level, but in this case there is a violent water hammer action, owing to the form of the end boxes, and to steam being generated in several of the tubes at once. Steam generated in the lowest tube pushes the water up into the upper tubes; the steam formed in the upper tubes tries to push this water back again at the same time that it pushes the water in front of it forward into the upper drum; and on this account when first raising steam the shocks are often very violent.

When properly in action the circulation is very vigorous and thorough, the alternating plugs of water and steam racing each other through the tubes of the element at a very high speed.

The amount of water in the tubes is, however, very small, excepting in the lowest tube of each element, which contains much more than any of the others. The circulation in the lowest tube of the element is least thorough, and is partly alternating.

Model of Yarrow Boiler (*Fig. 6.*)—It will be observed that one-half of this boiler is arranged with the tubes discharging below the water level, as in actual boilers of this type, and the other half with tubes discharging above the water level. An external downcomer is provided for each half, and a plug is provided so that the downcomer for the drowned tubes may be closed. Either half of the boiler may be used separately.

(1) Action with the submerged tubes and with the downcomer shut off.

As soon as the fires are lighted circulation commences, and when boiling first begins, plugs of steam and water are periodically projected into the upper drum, causing a considerable disturbance of the water level there. When the boiler is working at a high rate of evaporation, the discharge from most of the tubes is practically continuous, and the disturbance of the water level not so violent. Some of the tubes, which are not as highly heated as the rest, act as downcomers, while in some others the flow is alternating in direction. When the external downcomer is used, an improvement is observable in the general circulation; there is less alternating flow, but some of the tubes still act as downcomers.

When the other half of the boiler is used, in which the tubes discharge above the water level, there is, of course, no circulation until boiling begins, but on this account steam begins to be formed in the tubes nearest the fire almost immediately after the heat is applied.

This steam projects the water in the upper part of the tubes into the steam drum, cool water flowing from the drum through the downcomer to take the place of the water thus discharged. The action during warming up, then, is of an intermittent character, but, as the average temperature of the water in the whole boiler is increased, the intervals between the discharges become less and less, and when the boiler is working at a high

rate of evaporation the action is quite continuous. Each half of this model consists of sixteen tubes, in four rows, each tube being $\frac{7}{16}$ inch internal diameter, and the tubes in the different rows are opposite the spaces in the other rows. The internal diameter of the downcomers is $\frac{15}{16}$ inch, therefore the area of each downcomer is equal to $\frac{1}{3.4}$ of the area of all the tubes served by it.

Model of Thornycroft Boiler (*Fig.* 7).—This consists of twelve tubes, $\frac{7}{16}$ inch internal diameter, with a downcomer $1\frac{1}{2}$ inches in diameter. The area of the downcomer is therefore approximately equal to the area of the tubes served by it.

When heat is applied to this boiler, an intermittent discharge of plugs of water is almost immediately set up, due to formation of steam in the tubes, although the water in the upper and lower drums is practically cold. This action is obviously of great service in preventing overheating of the upper portions of the tubes which, before this action commences, do not contain water. In actual boilers of the *Daring* type, with internal heated downcomers, circulation of water between the drums will be started through the downcomers as soon as the fires are lighted. As before remarked, at high rates of evaporation, even with tubes below half an inch in diameter, the water and steam do not follow each other in plugs; the upper halves of the tubes are more or less filled with coarse foam, to the complete exclusion of continuous water.

Under these conditions the circulation is wonderfully active, and the water part of the foam is projected in a continuous stream right across the steam drum, as shown, the steam being given off freely, and the water level is only very slightly disturbed.

Model of Babcock Boiler (*Fig.* 8).—This model consists of three tubes, each $1\frac{7}{16}$ inches, internal diameter, and the distance between the centers of the headers is 33 inches. The tubes are inclined at 15° to the horizontal.

The circulation in this case is due partly to the entraining action of the bubbles moving through the inclined tubes, partly to the foam filling the upper ends of these tubes, but mainly to the column of foam in the front header. When the level of the water before starting is below that of the bottom of the steam

drum, a much smaller drum may be used, without priming taking place, than when the water level is above.

When the water level before starting is below the bottom of the steam drum (see Fig. 8, line A B), as soon as the boiler has got into full action a large amount of water is carried up into the drum along with the steam, and there is a continuous and very rapid flow of water along the bottom of the drum, as shown.

Model of Niclausse Boiler (*Fig.* 9).—In this model there are five tubes, each 1 inch internal diameter and 18 inches long. The internal tube is $\frac{3}{8}$ inch internal diameter, and the inclination is 15°. The action is practically the same as in the Babcock boiler.

EFFECT OF INCLINATION OF TUBE ON VELOCITY OF CIRCULATION.

When each tube draws its supply of water directly from the water drum, and discharges it directly into a steam drum, the greater the inclination of the tubes to the horizontal the better the circulation. If the tubes draw their supply from, and discharge their steam into, headers, the inclination of the tubes does not greatly affect the circulation, providing it does not fall below about 15°, and providing the currents from the different tubes do not interfere with each other. This is because the circulation in boilers of this type is mainly due to the low density of the foam in the upper part of the front headers. When the inclination is much below 15°, no matter whether the supply of water to the tubes is from a back header or is by means of internal tubes, the circulation is largely local, and the amount of water in the tubes is very small.

When the tubes are only slightly inclined to the horizontal, the only safe way of preventing the water being driven out of them is to use a non-return valve, or a very contracted orifice at the lower end of each tube: with a non-return valve the tubes may be quite horizontal.

RELATIVE ADVANTAGES OF ABOVE AND BELOW WATER DELIVERY OF STEAM.

When the discharge takes place just at the water level, it seems evident that the velocity of circulation must be a maximum, because the head of water effective for circulation is the same,

whether the discharge takes place at or below the water level. In the latter case, however, part of the energy due to this head is expended in giving motion to a considerable body of water in the drum, and the velocity of circulation through the tubes must necessarily be less than when the discharge takes place at the water level. If tubes are carried much above the water level the circulation is, of course, reduced in these tubes.

When the discharge takes place above the water level, the area of the downcomer is constant under all conditions, but when the discharge is below, this area varies even when external downcomers are used, because, the number of tubes acting as downcomers varies with the rate at which steam is being generated.

When the discharge takes place above the water level, a much smaller drum may be used for a boiler of a given power, and priming is less likely to take place, because the water level in the drum is only very slightly disturbed, whereas when the discharge takes place below the water level the disturbance is considerable.

SHOULD STRAIGHT OR CURVED TUBES BE USED?

From what has been said in connection with the action of the boilers when the fires are first lighted, it will be evident that when the discharge is above the water level, some parts of the boiler may be at a very much higher temperature than other parts. From this it seems to follow that, when the discharge is above the water level, provision must be made for free expansion of the tubes, either by bending them, or by leaving the ends free, as in the boilers of Belleville and Niclausse. When the discharge is below the water level, the temperature throughout will never differ much from that of the water, providing the circulation is good, and in this case straight tubes may be used without difficulty.

The author has found, by calculation, that when evaporating at the rate of 20 pounds of steam per square foot of heating surface, the difference in temperature between the inside and outside of the tube is only 2.6° Fahrenheit for each $\frac{1}{16}$th of an inch in thickness of the tube in the case of steel. The temperature of

the metal will, of course, be a few degrees above that of the water, but the more rapid the circulation the less the difference in temperature between the water and the tube. When working at the above rate, if the water be entirely driven from the heating surface for one second, and the thickness of the tube is $\frac{1}{8}$th of an inch, the rise in temperature in that time will be less than 10° Fahrenheit.

Assuming a difference of even 100° Fahr. between the temperature of some of the tubes and that of others, the difference in length in the case of a tube 5 feet long due to this difference in temperature would be only .04 of an inch. If the external diameter of the tube be $1\frac{1}{8}$ inches, and its thickness $\frac{1}{8}$th of an inch, the force necessary to prevent any increase in length due to this increase in temperature is 3.15 tons. This corresponds to about 8 tons per square inch of the metal, which is sufficiently below the limit of elasticity of mild steel to prevent injury to the boiler, even should the above unlikely difference of temperature ever exist between the different tubes of the boiler.

By using bent tubes it is possible to obtain a much larger amount of heating surface for a given number of joints, and a given amount of space occupied by the boiler.

RELATIVE ADVANTAGES OF HEATED AND NON-HEATED DOWNCOMERS.

With a given rate of evaporation from a given amount of heating surface, the greatest velocity of circulation will be obtained when all the heat is supplied to the upcomers; but if additional heat be applied to the downcomers, the velocity of circulation will be increased, so long as the amount of heat supplied to the downcomers is insufficient to generate steam with sufficient rapidity to nearly exclude continuous water at some part of the downcomers.

In all these models the velocity of circulation is increased by applying a moderate amount of heat to the downcomers. For this reason it is probable that the circulation in the Thornycroft boilers is more vigorous in those of the *Daring* type than in those of the *Speedy* type. In boilers where the discharge takes place below the water level, as in the Yarrow, Normand, Bab-

cock, D'Allest, &c., even when special external downcomers are provided, some of the tubes most remote from the fire act as downcomers.

In connection with downcomers it is important to note that the entrance to the downcomers ought to be removed as far as possible below the surface of the water in the drum, otherwise the reduction in pressure just inside the upper end of the downcomer may be sufficient to cause steam to be generated in it at that part. The steam thus formed would, of course, be condensed on its way down by the increased pressure. This action is indicated in Fig. 11. In connection with internal heated downcomers, insufficient attention has, I believe, been paid to the advantages of a few tubes of larger diameter being placed in the midst of tubes of smaller diameter.

DETERMINATION OF $\frac{\text{WEIGHT OF CIRCULATING WATER}}{\text{WEIGHT OF FEED WATER}}$.

When considering the best method to be adopted in order to determine this ratio, the author first thought that the best arrangement would be by means of a circular thin lipped orifice, of known dimensions, placed near the top of the downcomers, but it soon became evident that although this method might be adopted for cases where the discharge takes place above the water level, it could not be used in cases where the discharge is below the water level, because in these cases some of the tubes act as downcomers, no matter how large the external downcomer may be.

In order to get over this difficulty, the author used the model illustrated in Fig. 10, which consists of only one upcomer and one downcomer. By means of the loose glass tube shown attached to the brass rod in the steam drum, the discharge may be made to take place above the water level.

After trying various methods for measuring the circulation, it was found that the simple water column pressure gauge was the most convenient, and of sufficient accuracy for present purposes. In Fig. 10 this is shown attached to the top of the lower drum, another column being attached to the bottom of the steam drum

as shown. The head available for circulation is the difference in the heights of these two columns, and the velocity of the water in the downcomers is proportional to the square root of this difference of levels.

In connection with this, it is important to remember that this difference of level may be increased, either by an increase in the velocity of circulation, or by an increase in the resistance to the flow of the water from the upper to the lower drum.

The following results were obtained with this apparatus when working at atmospheric pressure and evaporating 13 pounds of water per hour. The evaporation per hour per square foot of heating surface actually subjected to flame being 10.8 pounds:

Area of downcomer.	Depression of water column.		Weight of circulating water / Weight of feed water		Remarks.
	Discharge above.	Discharge below.	Discharge above.	Discharge below.	
Sq. Inch.	*Inch.*	*Inch.*	*Pounds.*	*Pounds.*	
.087	21	18	40	37	
.359	8¼	7¼	147	138	
.994	3¼	3¼	242	242	The difference between these two readings was so small that it could not be read.

By means of the glass tube extension to the upcomer, it was possible to take the readings of the columns when discharging above, and when discharging below the water level, immediately after one another.

To determine the weight of circulating water in each case, separate tests were made for each size of downcomer with the upcomer disconnected, and the outlet from the bottom drum contracted to give a suitable difference of level between the columns. Water at about 200° Fahrenheit was then syphoned into the upper drum, and the weight of water flowing down the downcomer per minute, and the difference of level of the column being obtained, it was possible to determine, with considerable accuracy, the

weight of circulating water under the actual conditions of working as given in the above table.

When I commenced to write this paper, my intention was merely to describe the action in the various models shown, but as practically the whole of the problems connected with the design of water-tube boilers depend on the nature and amount of the circulation under various conditions, I was gradually led into a discussion of some of the most important problems which are affected by the circulation.

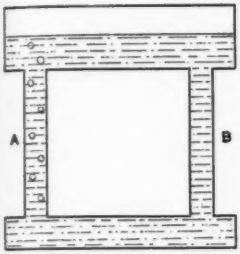


Fig. 1

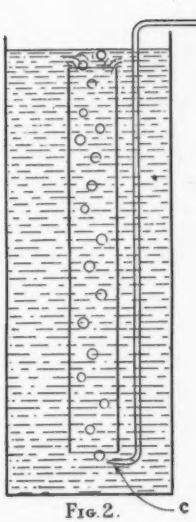


Fig. 2.

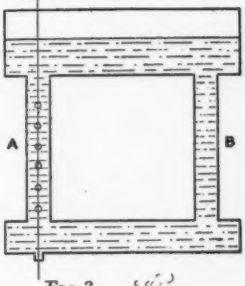


Fig. 3.

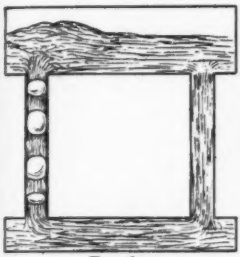


Fig. 4.

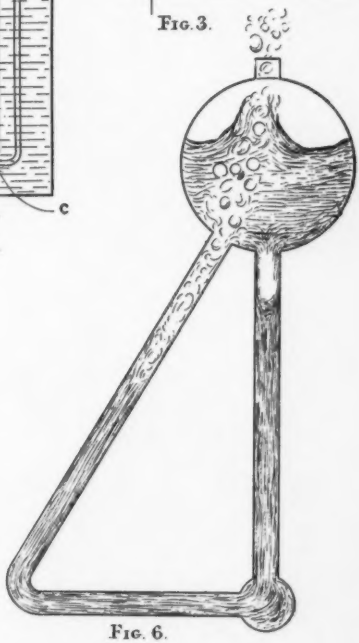
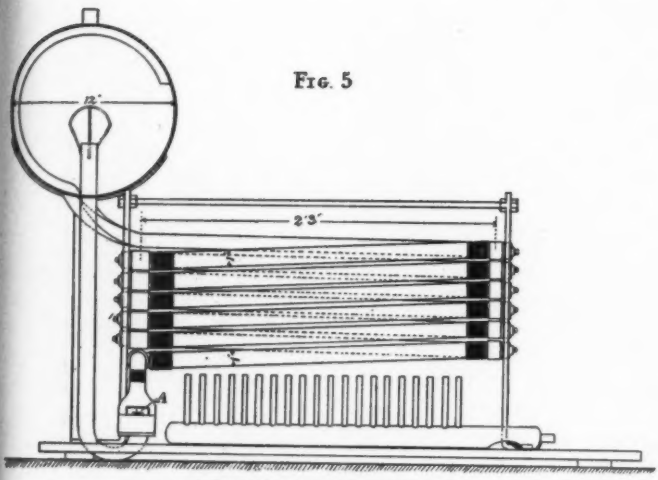


Fig. 6.

FIG. 5



MODEL OF BELLEVILLE BOILER.
(½ FULL SIZE)

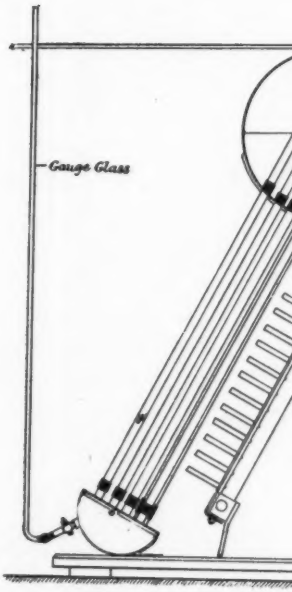
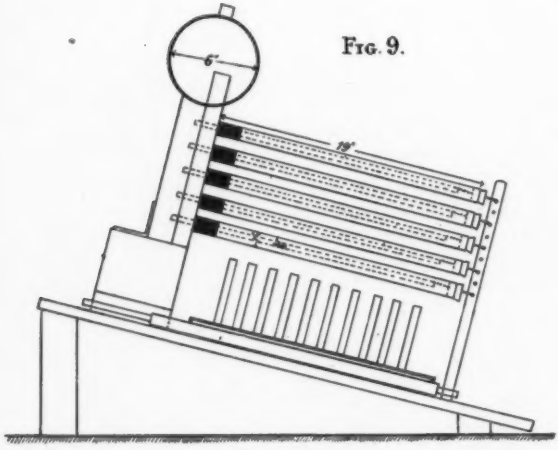
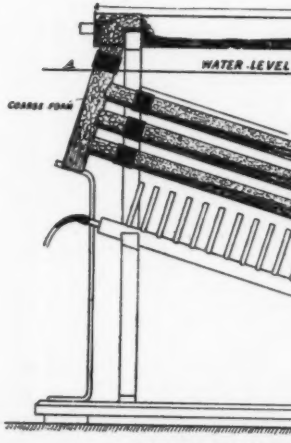


FIG. 6. — MODEL O

FIG. 9.





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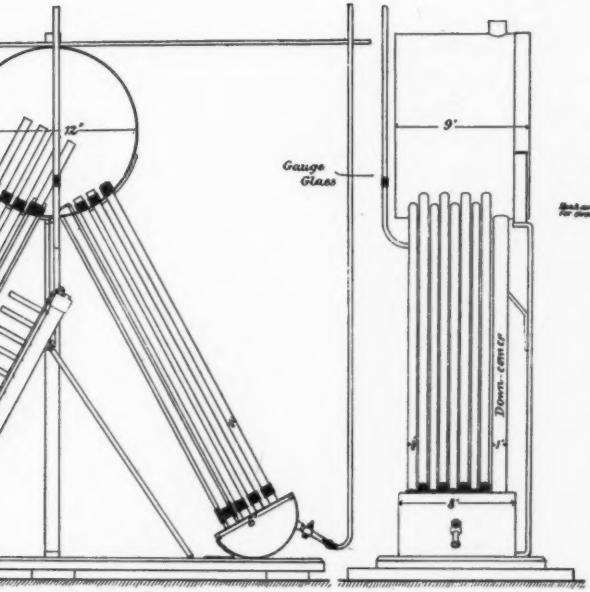
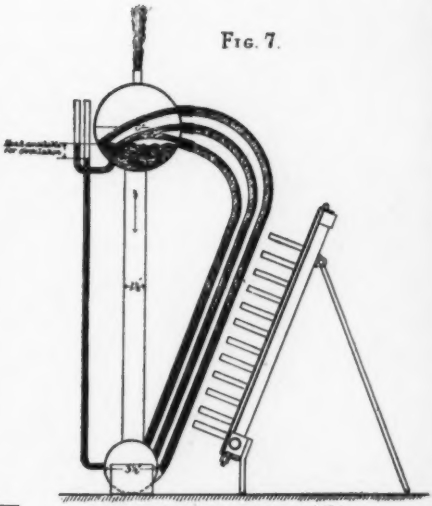


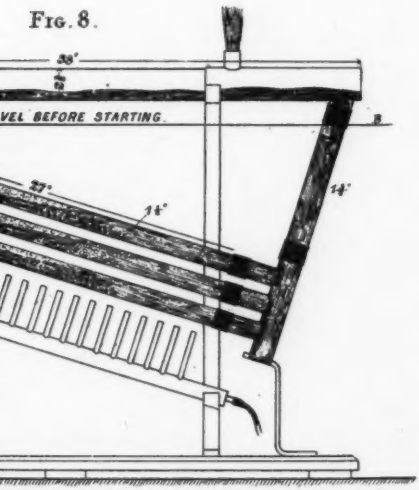
EL OF YARROW BOILER.

Fig. 7.



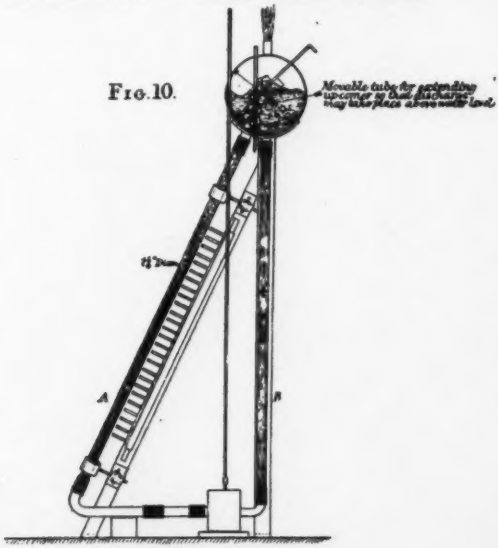
MODEL OF THORNEYCROFT BOILER.

Fig. 8.



CK AND WILLCOX BOILER.

Fig. 10.



EXPERIMENTAL BOILER.

DISCUSSION OF THE THREE FOREGOING PAPERS ON WATER-TUBE BOILERS.

[Compiled from London "Engineering" and the London "Shipping Gazette."]

Mr. A. J. Durston, the Engineer-in-chief of the Royal Navy, who opened the discussion on these papers, said he felt sure that they all appreciated the spirit which animated Col. Soliani in bringing his paper before them. To the able author of the paper on circulation in water-tube boilers great thanks were due, and also to Mr. Watt for his paper. It appeared to him (the speaker) that by arranging the tubes as Mr. Watt proposed in water-tube boilers, with the larger tubes closer to the fire, a more efficient working of the boiler would be secured, and that although the amount of heating surface would be reduced, this would be compensated for by its efficiency.

Regarding Mr. Watt's remarks on the inconvenience in working Belleville boilers when they are placed with the axes of the generating tubes athwartships, and when in a seaway, he would say that in the *Powerful* and *Terrible* only one-third—the forward third—of the boilers are so placed, the remaining boilers in these, as in all other ships of the Navy, being placed with the axes of the generating tubes in the fore-and-aft line. That is, about 264 out of 296 boilers are so placed.

There were reasons in favor of the athwartship distribution of tubes, which was adopted up to the present time in a considerable number of ships on the Continent, but on the whole, he thought that he and his colleagues were in favor of the fore-and-aft distribution, as shown by their action.

That the fears of the author are groundless, even when the tubes are placed athwartships, was shown by the fact that all of the vessels of the Messageries Maritimes Company are so arranged, and these vessels make regular passages between France and New Caledonia in all kinds of weather. Practical experience

upon the subject was worth much. These large ships made their ocean voyages regularly without any of the difficulties referred to by the author.

Inquiries made on board the *Ville de la Ciotat*, which recently arrived at Marseilles, brought out the information that during the three months' voyage there was not the slightest leak in any part of her boilers, and no repair was necessary to a single element. They had had two years of experience in actual service with the *Sharpshooter*, which had Belleville boilers, and no repairs had been necessary to the boiler tubes.

Another of the Messageries boats had completed over 300,000 sea miles of regular steaming, with no material defects, and the Chief Engineer had reported that he could, if necessary, have left again for Australia on the following day.

Referring to Professor Watkinson's paper, they were indebted to Mr. Yarrow's recent experiments for the fact that, by adding heat to a downcomer tube within certain limits, the circulation was not impeded, but actually increased. Professor Watkinson had added materially to that information by showing the limits within which that adding of heat to a downcomer tube must be kept. The Professor had stated in his paper that when an external downcomer is used, an improvement is observable in the circulation. This agreed with Admiralty experience up to date with torpedo boats and destroyers.

Prof. Watkinson had remarked that in starting the Belleville boiler it is necessary to have water in all tubes, in order to prevent overheating of the upper tubes. He presumed that this referred to the glass model only, for it was certainly not necessary in the actual boiler. With reference to the remark that, when raising steam in this boiler, a water hammer is experienced, practice both in the Navy and elsewhere had shown that no importance need be attached to this matter.

Prof. Watkinson had referred to the effect that the temperature of the metal of the boiler tubes would have in being a few degrees above that of the water, and had assumed a difference of 100 degrees Fahrenheit as an extreme case.

Mr. Durston considered that the author was mistaken as to

the amounts of such difference met in practice, and he would give two examples. The first was a carefully conducted experiment made on the tank boilers of the *Vulcan*, where a gauge rod was inserted to measure the difference between the expansion of a boiler tube and that of a rod near it of the same temperature as the water in the boiler. This difference gave the excess temperature of the tube beyond that of the water. It was found that, when working with an air pressure of $\frac{7}{10}$ inch of water, on a natural draft trial, the tubes at the middle of the nest were a mean of 180 degrees Fahrenheit hotter than the water in the boiler. Again, a recent experiment was made to ascertain the same thing in the bottom tube of one element of a Belleville boiler. It was found that, when burning coal at various rates, the increase of temperature varied from 60 degrees at very slow rates of combustion to 210 degrees Fahrenheit at the highest rate. This was with a clean boiler, and it would be understood that when the boiler tubes get a little dirty these temperatures are liable to be increased. Referring to small tube boilers, with tubes between treble plates, it was known that tubes with little or no original curvature do bend under service conditions, and are often found to be considerably distorted.

Respecting the question of bent *versus* straight tubes, Mr. Durston said that an important consideration was also that, no matter what precautions might be taken, there would be occasional shortness of water in such boilers, and, under such circumstances, the resulting damage to a boiler with bent tubes would be much less than with boilers with straight tubes.

Turning to Colonel Soliani's paper, Mr. Durston took exception to the modest statement personal to the author, wherein he describes himself as a dilettanté in marine engineering. He believed Colonel Soliani occupied the position of Engineer-in-Chief of the Italian Navy for some years previous to succeeding to his present position of Director of Naval Construction, and many eminent engineers in this and other countries were well acquainted with his high attainments as a marine engineer. Colonel Soliani has proposed a type of compound marine boiler for certain reasons which he said would be of advantage to the mercan-

tile marine as well as for naval purposes. Of the advantages to the mercantile marine, Mr. Durston would not advance any opinions, but concerning the purposes of the Navy, he submitted that whatever advantages this boiler contained, it certainly retained the disadvantages of large diameter and corresponding thickness of shell plates, together with large water spaces and volume of water contained. No mention was made in the paper of the steam pressures it was proposed to work this boiler at, but, from the engraving in the paper, the boiler did not appear to be suitable for pressures much in excess of 200 pounds per square inch. The arrangement of water tubes, too, did not seem to lend itself to convenient access to the ends of the ordinary smoke or fire tubes.

The reason given for the proposed design was that the vitality of cylindrical boilers may be increased, and the struggle prolonged even for Navy purposes. This did not appear to the speaker consistent with the view that progress in the direction of the use of higher pressures was desirable. It had been stated in public official papers that the Admiralty were using water tube boilers of the small tube type for vessels of the torpedo fleet; and for special ships, such as the third-class cruisers of the *Pelorus* type, and that for battleships and for first and second class cruisers, water tube boilers of the large tube type were being adopted. There was another class of small vessel used for what might be called river or police purposes, such as sloops, and in these Mr. Durston considered it was desirable also to use the large tube type of water-tube boiler. One of the reasons for this distribution of water-tube boilers was that the large tube secured a fair amount of thickness to take up the wear and tear of use and work, and a size of tube admitting of easy examination and correct ascertaining of the condition of each tube. It was considered desirable to say of such boilers that with the replacement of an occasional tube, they should last three commissions of three years each at least; whereas with the thinner tubes of the small tube type of water-tube boiler it could not, according to present experience and knowledge, be guaranteed that more than from three to five years of life would be secured.

In conclusion, Mr. Durston said that his remarks had necessarily been confined to that part of Colonel Soliani's paper which related to Navy boilers; with his other conclusions as regards Navy practice the speaker was glad to concur.

Mr. Yarrow said he was sure the Institution was under a very great obligation to the three authors for the papers, and particularly to Professor Watkinson for showing his interesting experiments. He would draw attention to that part of Mr. Watt's paper in which reference was made to the evaporative efficiency of the various rows of tubes. It would be seen that the two rows nearest the fire actually evaporated 84 per cent. of the total, the seventh row giving only one-half per cent. That there existed such large variations in the evaporative efficiency of the tubes, dependent upon their situation, was well known to those who had made this subject a matter of experiment. The speaker would submit, however, that the rapid reduction in the evaporative efficiency in heating surface, as such surface became more and more remote from the furnace, was occasionally not sufficiently realized in actual practice. In the course of his firm's experience they had been frequently asked to submit designs of boilers, both of the water-tube and tubular types, and it often happened that a demand was made that there should be more heating surface, even if it could only be obtained at the sacrifice of efficiency in circulation, or a reduction of combustion chamber capacity. He would point out that the figures given by Mr. Watt were instructive, as showing the little gain secured by an addition to the heating surface remote from the fire. Frequently, perhaps generally, when extra tube surface is insisted upon, the gain by this additional heating surface is obtained at a very much larger sacrifice, due to the loss owing to reduced circulation or to the less perfect combustion. Mr. Yarrow was informed that Continental engineers have realized the general principle to which he referred. In the Du Temple boiler he believed those portions of the tubes which were nearest the fire were actually reduced in diameter, so as to secure better combustion, although it was obtained at the sacrifice of heating surface. From the re-

sults of experiments he believed that the capacity of the combustion chamber, and the means for the proper intermingling of the gases, so as to secure the most perfect combustion, should be considered as a matter of the first importance, even often before the extent of the heating surface, more particularly if that surface is in close proximity to the fire, thereby cooling the gases, putting out the flame, and diminishing the actual heat generated. Professor Watkinson's experiments, the speaker said, were of the deepest interest, and extended over a larger range of types of boilers than he believed had been attempted before. They afforded a ready comparison of the rapidity of circulation in different types of boiler; but, Mr. Yarrow pointed out, it must be borne in mind that the experiments just put before the meeting were all carried out under atmospheric pressure. Allowance would have to be made for the altered conditions under which boilers work in practice. He believed that whatever the circulation might be under atmospheric pressure, it would generally be more rapid and more permanent under high pressure.

Professor Watkinson in his paper had referred to the slightly increased circulation when tubes entering at the bottom of the steam drum were carried above the water level. Mr. Yarrow had tried experiments in this direction, and admitted that such was the case when the tubes were carried up in the direct manner described; but he would point out that by carrying the tubes up into the steam drum, the difficulty of gaining access to the interior of the drum, and of cleaning both it and the interior of the tubes, was greatly increased. He would further point out that water was much more apt to pass into the steam pipe through being driven upwards with the steam. He differed from Professor Watkinson's conclusion that a smaller steam drum can be used when the tubes deliver at the water level; in fact, he thought that the steam drum must then be greatly increased in size and must be provided with a series of baffles. He concluded from what Professor Watkinson had said that he found increased circulation to be caused by the heating of the tubes in which the down currents exist. This fact Mr. Yarrow had for some time

maintained. He was pleased to hear the author give it as his opinion that drowned tubes were, for practical purposes, all at the same temperature. Those next the fire were undoubtedly subjected to greater heat than the others, but any increase of length due to this increase of heat might be disregarded.

Straight tubes in water tube boilers had now been successfully used for many years, and he believed that in boilers of the type in use at present the lowest estimate might be taken at 200,000 tubes. He thought that they might confidently say that there was no need for any fear in using straight tubes in water tube boilers, provided that efficient circulation was insured.

Straight tubes secured facility in cleaning and examining their interior surfaces, simplicity and cheapness of construction, and convenience as regards spare gear. Any substance getting into a straight tube would fall through it, while in case of a curved tube, it might result in blocking the tube. His firm still continued to galvanize tubes internally, believing that this increased durability. There was no danger in doing this with straight tubes, for, should any of the zinc scale off, it would fall through. Mr. Yarrow was aware that objection existed to galvanizing tubes internally, on account of the generation of hydrogen, but this was experienced only when the boiler was new, and would be guarded against by ordinary precautions.

Mr. Yarrow referred to certain new features in boiler practice and to the system followed at his works of expanding tubes by steam, by which a large saving in time and cost was secured.*

Mr. Normand, of Havre, thought that in the splendid experiment which Professor Watkinson had allowed them to see, a great difference was noticeable between small tubes and large tubes. Everybody knew what was called the steam loop. That could exist in small tubes, but never in large ones. As to his boilers, Mr. Yarrow had referred to the fact that the heating tubes were of less diameter in the lower part; the object was to allow the flame to penetrate among the tubes at that part. He had, however, abandoned the practice. He never put tubes of

* A description of the above will be found under "Notes" in this number.

two diameters in the lower part. It was very dangerous, as anything coming down the tubes stopped when it got to the small part of the tubes. As to the difference of temperature between the steam and the metal of the tubes, he quite agreed that the difference was very great, and the best proof of it was that pure copper tubes that ought to resist a very high temperature had given very bad results. He considered that steel, or more especially iron, was a more reliable metal, because steel had as little carbon in it as possible. As to the height of water above the opening of the tube, if they let the air escape a little under the water the velocity of discharge was exactly the same.

Mr. J. I. Thornycroft said he felt that the Institution was particularly indebted to the authors for the able manner in which they had put their subjects before the meeting. He thought that for the purposes of the navy the attempt to make the old drum boiler last longer, as proposed by Colonel Soliani, was a vain attempt. With regard to the model which Mr. Watt had brought before them, he would only say that the model proved too much. Mr. Watt had said that the evaporation was reduced from $8\frac{1}{2}$ ounces to 5 ounces by turning the tubes towards a vertical position, but that gentlemen's experiments only proved the fact of a change in a particular boiler.

Taking a line from the trials of Professor Kennedy, this boiler gave an efficiency greater than unity, which was more than they could be expected to believe.

He thought that M. Normand did not quite appreciate Professor Watkinson's point with regard to the fact of the rapid velocity at the top of the downcomer. With regard to the temperature of the tubes, what Professor Watkinson had said was, that the difference in temperature between the two sides of the tubes was limited, and his conclusions debarred any change of temperature between the tube and the water. He thought that the experiments that Mr. Durston had spoken of, where the expansion of a tube was actually measured in a real boiler at work, showed an expansion which would not have been expected, and which afforded very valuable data. He had always advo-

cated straight tubes with regard to the circulation in the different boilers. One of the most important points that Professor Watkinson had made was the fact that it was most important to discharge the water above the water level in the circulator drum. In a paper that he (the speaker) had prepared for the Institution of Civil Engineers, he defined circulation as "the orderly process of the water through the boiler." As to the difficulties due to the outcomers becoming sometimes downcomers, and an alternating motion taking place so that the water went alternately up one tube and down another, the circulation then became confused and liable to lead to disaster.

Mr. Leslie Robinson asked Professor Watkinson if he would mind repeating the explanation which he had given as to the reasons that caused him to alter his opinion with regard to the circulation being better without the outside downcomer. Some of them were still rather at sea upon the point, and he thought that a lucid explanation would be of use. He pointed out the necessity of engineers being more precise in calculating heating surfaces. It was necessary to determine on what basis estimations should be made, and what should be the values given to areas of heating surface in different parts of the boiler.

Mr. Thom, of Glasgow, said he had tried a number of experiments with a water-tube boiler, similar to the Niclausse, to improve the circulation, and then he took out the internal tubes altogether to see what the result would be without more circulation than the spasmodic action of blowing out the tube. He found out that the result was exactly the same with circulation as without it. With regard to the Belleville boiler all the steam was generated at the bottom, but there was practically no circulation in the bottom tubes, so that the question was, Was there any real advantage in increasing the circulation above the amount which would make the boiler work perfectly without giving trouble? It was quite correct to say that the larger pipes were better for downcomers and the smaller for upcomers. In reference to compound boilers, he had been at sea for a short time,

and he considered that the combustion chamber was the only part suitable for high pressures, because they could set it to any amount within plates and get very efficient results, because it always kept clean. By changing the flow of the gases instead of the flow of the water inside, they could make as much as 50 per cent. difference in the efficiency of the boiler.

Mr. Blechynden said that the most important thing that he had learnt since he had come into the meeting was that experiments might teach too much; in other words, they might draw general conclusions from experiments where they had no right to do so. Some of the conclusions which had been drawn in regard to the amount of vibration, or the change of the amount of vibration, when the tubes were placed at different angles, might be very simply explained. When the boiler was lying with the tubes nearly horizontal, the whole of its surface was exposed to the heat; when the boiler was inclined, the flow of the gases would tend upwards. Whether that always happened, depended on the volume of heated gases that was caused to flow through the tubes. If it was large it would tend to flow direct across the tubes. The quantity which each row of tubes would evaporate was, he believed, too generally stated. That also depended on the quantity of gas that was passing through the tubes and on the initial temperature. Experiments on a large scale, from which a general conclusion might be drawn, showed that the temperature at one point was something like 1,200, and at another point 400. In some experiments that were made with a boiler, there was a series of generating tubes, then a wall of tubes, and the boiler was fitted with downcomers which were capable of being opened and shut, and it was found that under certain conditions even with the ordinary downcomers closed, no motion could be got downwards when the fires were forced considerably so that a large quantity of gas was passing through; but when the fires were kept thin and very intense there was downward motion.

There was a popular fallacy that copper was much more effective as heating surface than iron or steel; when copper was

clean, it was not so good a conductor as iron, but if dulled by smoke, the efficiency of the two metals as conductors was the same; any one could prove that by means of two new kettles.

Professor Lambert said that Professor Watkinson had stated that with a given rate of evaporation from a given amount of heating surface, the greatest velocity of circulation would be obtained when all the heat was supplied to the upcomers, but if additional heat were applied to the downcomers, the velocity of circulation would be increased, so long as the amount of heat supplied to the downcomers is sufficient to generate steam with sufficient rapidity to nearly exclude continuous water at some part of the downcomers. By this statement a limit was fixed, a fact to which Mr. Durston had referred; but the speaker would point out that the limit was not attained in actual practice. Mr. Yarrow had made a very remarkable experiment in regard to this matter. He had taken a U-tube, the top ends of which led into a closed drum; he had applied three Bunsen burners to one leg A of the inverted syphon, and in that way had set up an upward circulation in A; he had then applied five large burners to the opposite leg B, and the circulation had continued in the same direction, but at an accelerated rate. Finally, the three Bunsen burners had been removed from A, the five burners still supplying heat to B, and the circulation had still continued in the same direction, showing that, with heat applied only to a downcast leg, circulation could be maintained. This experiment was carried on with steam at 130 pounds pressure; the result was startling, but it proved what Professor Watkinson advanced. The same author had referred to a case in which sufficient steam was generated to exclude water in a down tube. The speaker had never seen any bubbles formed in a down tube. Those who had had the advantage of watching Mr. Yarrow's experiments would know that circulation was always more steady when working at higher pressure, as compared to the water in the boiler being subject only to atmospheric pressure, and change in the direction of circulation hardly ever occurred under high pressure. In the early part of his paper Professor Watkinson had given the causes of

circulation. First came the difference in density of water, due to difference in temperature. When fires were first lighted, the circulation was very sluggish. Next they had the case of isolated bubbles, the continuity in the water column not being broken; the circulation, the author said, was then mainly local, and was set up by the entraining action of the bubbles of steam rising through the water. Thirdly, there was the case of generation of steam being so rapid that a part of the steam generating pipe was filled with steam or water, and then circulation was due to the difference in density between this steam or foam and the continuous water in the downcomers. In regard to the first and third causes enumerated, he agreed with Professor Watkinson's conclusions, but he questioned the accuracy of the intermediate case. He was not quite sure of the exact meaning of "entraining," but concluded it meant frictional drag. He did not look on that as the right explanation of the phenomenon. He was of opinion that the force of circulation was in all cases due to the difference in weight of the up and down comers, and not to entraining action. The bubbles rose from internal action, and they had therefore equal and opposite forces, which could not cause movement of the water column as a whole. He preferred to put down the action of circulation to the difference between the weights of the two columns. Professor Watkinson had illustrated his case by supposing a string of beads strung on a wire and then raised. In that case, however, he introduced an outside force, and therefore the beads were not comparable to the bubbles of water.

Mr. C. H. Wingfield said that Professor Watkinson only took account of those bubbles which were close to each other and formed a sort of foam. He (Mr. Wingfield) thought that every single bubble, whether it separated the water or not, either assisted or resisted the circulation. A bubble in the downcomer undoubtedly resisted the circulation, because it reduced the weight of the downcomer, and he thought that there really could not be two opinions on the point, that the circulation was due simply to the difference in the total weight, or the density, if they liked to call

it so, of the column moving downwards and the column moving upwards. When a downtake was fitted to a given boiler, at least twice as much steam could be safely generated as would be the case with the same boiler without downcomers. He concluded that with a given rate of steam production, the liability to become overheated was at least twice as great without special downcomers as it was when they were provided. As to copper tubes, he believed it to be true, as Mr. Milton said last year, that the reason why copper steam pipes gave way was not that they were burnt at all, which meant the addition of oxygen, but that they deteriorated through loss of oxygen, which was exactly the opposite. Mr. Milton had found that if a copper pipe was worked in a smoky flame that deoxidized the copper and reduced its strength to such an extent that it was what was called burnt, and was liable to give way. He (the speaker) thought that copper was a most unsuitable material, whether it was overheated or whether it was not.

Professor Watkinson, in commenting on the other two papers, said in regard to Colonel Soliani's proposals that he always looked on the great weakness of the water-tube boiler being attributable to the fact that the tubes could not be plugged without letting down steam and emptying the boiler. Its redeeming feature, however, was that the quantity of water contained in it was small. Colonel Soliani's boiler contained a great deal of water, and it was not possible to plug the tubes. Mr. Watt had said that in a water-tube boiler the outer rows of tubes were of little use. This he believed was a common mistake. If the gases were better mixed, and moved quickly enough, then, assuming that the tubes were staggered, with the exception of the two rows of tubes exposed to the radiant heat, the rest of them were doing practically the same amount of generation, no matter how far they were removed from the fire.

Colonel Soliani, in replying to the discussion, said there was still something lacking in water-tube boilers, and he thought that the compound boiler gave advantages which would pave the way

for the more considerable introduction of the water-tube boiler. He did not wish to be misunderstood in this matter; he was an advocate of water-tube boilers, and they were an accomplished success in small fast vessels. For craft of this type he would use, therefore, a pure water-tube boiler, but for larger vessels he preferred the compound boiler. The latter had an advantage of being able to get large power with few boilers. Comparing, for instance, the *Powerful* and *Campania*, which had machinery of about equal power, they found 48 Belleville boilers were necessary to do the work that was obtained from 12 return tube boilers. That meant additional supervision. In conclusion, he wished to express very fully his grateful thanks for the kind welcome he had received from the members of the Institution.

Mr. Watt, in reply, said that with regard to the remark of Mr. Thornycroft that the experiments, that he (Mr. Watt) had conducted, proved too much, he might state that the experiments were conducted on nearly the same principle throughout, with the same fair play to one experiment as to another, and the difference of a few degrees between the angle of the tubes would not in any way affect the result. He got an evaporation at, say, 10° with one result, if he altered that to 20° or 30° he got quite a different result, and Mr. Thornycroft had not shown why that had taken place. Mr. Blechynden had attempted to show it, and had mentioned that the boiler was angled to such a degree that the whole of the heat went towards the top. He experimented in different ways and had the funnel placed at the bottom end, and instead of the heat getting to the top it got to the bottom, with the same result, so that Mr. Blechynden's idea was entirely wrong. The results that he (the speaker) got were similar to what were got in an ordinary boiler with a vertical heating surface. Two square feet of vertical heating surface were only about equal to one square foot of horizontal heating surface; they could not get the same amount of steam generated out of a vertical as out of a horizontal heating surface. A good deal had been said on the circulation of the water in the boilers. He had not gone into

it at all, but they had before them two kinds of circulation, and the two were quite distinct.

Professor Watkinson, in replying to the discussion, referred to Mr. Durston's statement as to the great difference in the temperature of tubes which had been shown by experiment. He would point out that in that case there was possibly very bad circulation. The proper way, however, to test the conductivity of metal was by means of a long rod taking the amount of heat passed through it, and not by putting plugs of metal in between the sides of the plate. If there was a good circulation, then the difference in temperature should certainly never rise to 100 degrees.

Mr. Durston, in explanation, said that the temperature had been taken in the case alluded to, by measuring the expansion of the tube, and calculating the heat that would be required to produce such expansion.

Prof. Watkinson said, in regard to the bending of the tubes, where the tubes were fastened directly between two tube plates, Mr. Durston had remarked that that showed a great difference of temperature, but that difference occurred in the case of the Belleville boiler, and one advantage claimed for the Belleville boiler was that the tubes were free, so that that seemed to show that the explanation given by Mr. Durston did not fully cover the case. Mr. Yarrow objected to discharging above the water level, but he (the speaker) adopted that method simply to enable him to compare the circulation under two different conditions, and did not propose it for a practical boiler. If he had done so, he would have arranged to take the steam out of the bottom, or somewhere near the bottom. Mr. Yarrow had also remarked that, in the case of the Thornycroft boiler, the tubes were liable to overheating during the time that the boiler was being warmed up. But he (Professor Watkinson) thought that owing to no circulation taking place at the beginning, steam was generated almost as soon as the fire was lighted, so that they had steam and

water going through alternately, and that prevented overheating. Mr. Robinson had asked him why he had changed his opinion as to the circulation being better without the outside downcomer. He had changed his opinion by sitting opposite the tubes for some hours and watching them under different conditions, and he thought that the circulation was better without the outside downcomer, because the length of the foam column was greater.

Mr. Thom had referred to an experiment that he had made with a boiler without the internal circulating tube. Tubes might be made to stand if they had nothing but steam in them, and in the marine superheaters they were arranged to stand with the flame playing right on them. Sufficient water managed to fall down through the steam to prevent superheating. With regard to Professor Lambert's remarks, he (Professor Watkinson) left out the part of the paper referred to, because he believed it to be of less importance than the other. It did not matter a great deal, so long as they got a good circulation, whether it was correctly described by entraining action or by difference in density. He used the word entraining because it expressed his idea better than any other word. If they got alternating steam and water then they got rapid and most efficient circulation. One experiment that he had tried was that he took shot of a density of about eight times that of water, and he poured the shot down the internal tube and found very great elevation. He arranged to deliver the shot without initial velocity, and he got an exceedingly slight difference in level.

MEASUREMENT OF FEED AND CIRCULATING WATER, ETC., BY CHEMICAL MEANS.

By C. E. Stromeyer, Esq., Member.

[Read at the Thirty-seventh Session of the Institution of Naval Architects, March 26, 1896.]

It is well known that the quantity of air which enters a furnace, or of the gases which pass up the funnel, cannot be accurately measured by any mechanical means, and in all modern boiler trials, where it is desired to estimate the true weight of the waste gases, recourse is had to chemical determinations. A careful analysis is made of the carbon contained in the coal, and of the carbon (in the form of carbonic acid) contained in the waste gases, then by multiplying this ratio into the weight of coal burnt per hour, the weight of the waste products is obtained. This weight is then multiplied into the specific heat, and into the difference of temperature of the air which enters the furnace, and that of the gases which pass up the funnel; and the product is the heat carried away. Complicated though this method may appear, it gives results which are far more accurate than any that can be obtained by direct measurements with an anemometer, and it therefore occurred to me, that a similar process, if simplified, might with advantage be applied to the measurement of streams of water not only on land, but also at sea. As will be seen by the experiments detailed in this paper, I have succeeded in measuring both the amount of steam condensed and the circulating water of a marine engine, a task which does not appear to have been previously attempted; the results, too, are sufficiently accurate to compare well with those obtained under more favorable conditions on land engines, in which cases the measurements have always been made by positive and mechanical means.

An inquiry amongst my chemical friends elicited the fact that there are many simple tests for chemical substances, which might

be depended upon for estimating them to within one-millionth of the weight of water in which they may be dissolved. The nitrate of silver test for salt (sodium chloride) is one of these, and it was therefore decided to try by this method a preliminary experiment on the feed water of a marine engine. A measured quantity of salt (sea) water was slowly injected into the condenser of the engine while at work, and subsequently a chemical analysis for salt was carried out, both on a sample of sea water and on a sample of this adulterated feed. Supposing that their salinities stood in the ratio of 100 to 1, and supposing that the rate of injection of the sea water was half a gallon per minute, then evidently 495 pounds of steam had been condensed during the same period, with which the injected sea water had been diluted down to a 1 per cent. solution. 49½ gallons per minute would therefore be the volume of condensed steam.

MEASUREMENT OF FEED SUPPLY TO LAND BOILERS.

The value of such a method of measuring quantities of water will, of course, depend upon the accuracy attainable, not only as regards the chemical tests, but also as regards the whole process. Being unable to make comparative tests by this process as well as by calculated measurement of the feed water of a marine engine, an experiment was carried out ashore, in which the results could be compared with the readings of a water meter. It is well known that all town waters contain small quantities of salt in solution; in order, therefore, to find the quantity of water which has been fed into a land boiler, it was only necessary to take daily samples, both of the feed water (town water), and of the boiler water, and to ascertain the relative daily increase of weight of salt in the boiler. Now although the Glasgow supply, which is considered to be one of the purest drinking waters, contains only between one and two grains of salt per gallon, or about one five-hundredth per cent. by weight, yet the nitrate of silver test is so accurate that it can be depended upon to determine the exact amount to within one per cent. In carrying out this experiment I was at first seriously inconvenienced by irregular results, but found that these were due to condensed water in the water gauge

pipe from which the samples had been drawn. In subsequent experiments a cock was fitted direct to the boiler shell, and from that day the readings were regular.

The results are contained in Table I. The meter readings were commenced on Monday about noon, and ended on Saturday at about the same time. The town water was constantly running into a large tank holding about 5,000 gallons, from which a sample was daily taken for analysis. The feed was drawn from this tank and pumped into two externally fired boilers, of which the smaller one was worked 9¾ hours per day while the large one was worked irregularly, sometimes throughout the night. The respective working hours during the five days of the trial were 48½ and 78¼ hours. Of course, these boilers were under steam for nearly the whole period of 119¼ hours. Another set of samples of water was daily taken from each boiler and analyzed. On these occasions the height of water in the gauge glass was noted, as well as the steam pressure, for the salinity of the boiler water had to be corrected on account of the evaporation which would take place during the time that it was being blown into a bucket for sampling. Thus the heat contained in the water while in the boiler would be proportional to its temperature, say 322° Fahrenheit. Immediately after leaving the boiler, its temperature would be lowered to 212° Fahrenheit and the heat thus liberated would evaporate a certain amount of water, which ought, of course, to be returned to the samples when cold. It amounted to about 15 per cent. The readings of the water-level were necessary in order to be able to estimate the volume of water in the boiler, which had also to be corrected on account of the difference of expansion of the boiler and the water within it. Both corrections have been carried out in the table, and amount roughly to 20 per cent.

It will be seen that the absolute weight of salt in both boilers could be estimated from the chemical test. It slowly increased from 10,830 grains (=1½ pounds) to 56,930 grains (=8⅛ pounds), or from .006 per cent. to .032 per cent. As the average saltness of the town water was 1.31 grains per gallon, it required 35,430 gallons to supply the 6⅝ pounds (or exactly 46,100 grains) of

TABLE I.—CHEMICAL ESTIMATE OF TOWN WATER FEED SUPPLIED TO A PAIR OF LAND BOILERS.

Day of week. (Noon.)	Main boiler.			Auxiliary boiler.			Weight of salt in both boilers.	Daily increase of salt.	Saltness of feed water.	Estimated daily volume of feed water.	Working hours.	
	Corrected water volume.	Corrected saltness of boiler water.	Weight of salt in boiler.	Corrected water volume.	Corrected saltness of boiler water.	Weight of salt in boiler.					Main boiler.	Auxiliary boiler.
	Cubic feet.	*Grains per gallon.*	*Grains.*	*Cubic feet.*	*Grains per gallon.*	*Grains.*	*Grains.*	*Grains.*	*Grains per gallon.*	*Gallons.*	*Hours.*	*Hours.*
Monday.....	266.2	3.40	5,640	150.4	5.54	5,190	10,830	...	...	...	...	...
Tuesday.....	269.3	9.18	15,410	142.3	8.51	7,550	22,960	12,130	1.32	9,190	21	9
Wednesday.....	264.4	12.05	19,860	139.5	11.84	10,300	30,160	7,200	1.29	5,580	12	9
Thursday.....	264.8	15.79	26,070	140.5	14.73	12,900	38,970	8,810	1.46	6,040	12	9
Friday..	268.8	17.82	29,860	146.2	17.77	16,200	46,060	7,090	1.24	5,720	9	9
Saturday.....	268.6	22.75	38,100	144.9	20.83	18,820	56,920	10,860	1.22	8,900	21	9
Totals.....	...	80.99	...	...	79.22	...	...	46,000	6.53	35,430	78¼	48¼
Means.....	...	16.20	...	...	15.85	...	...	...	1.31	7,086	...	...

salt, and that is the estimated volume of the feed. During this period of 119¼ hours, the water meter recorded 37,270 gallons. The difference, exactly 1,840 gallons, may be due either to an error of 5 per cent. in the chemical determination of the feed, equal to $\frac{1}{15}$ of a grain per gallon (which will be discussed later on), or it may be due to a slight leakage of 30 gallons per day, say 1¼ gallons per hour, which is only .4 per cent. of the feed supply. It must be remembered that the average saltness of the boiler water is 16 grains per gallon, while the feed only contains 1.31 grains, and a leakage of 150 gallons in five days would carry away 2,420 grains of salt, which is as much as would be supplied by the above mentioned 1,840 gallons of missing feed water.

A method which will, under such exceedingly difficult conditions, give a result that is correct to within .4 per cent., is surely worthy of a more general application. I would, however, wish to point out that, although in this case all the readings and the samples were taken by the boiler attendant, so that it would seem as if this method could be easily applied to land boilers, yet, as there are certain precautions which must be taken to ensure the desired accuracy, I would not recommend it for general use. These precautions are, that the boilers should be filled with fresh water before starting, otherwise the loss of salt due to even small leakages will be excessive; leakages should, if possible, be stopped entirely; and, unless the samples and water gauge readings are only taken on two succeeding Sundays, when there is no steam in the boiler, it will be necessary to make careful allowances for the boiler temperatures, the corrections amounting to about 20 per cent. for a working pressure of 80 pounds per square inch.

MEASUREMENT OF FEED BY SALT BRINE INJECTIONS.

The above experiments were, as already mentioned, undertaken for the purpose of checking the results of some trials at sea, which, it had been vainly hoped, would contain sufficient internal evidence either to confirm or condemn the method. It was believed that the steam weights, as estimated from the indicator cards, would be found to stand in some definite relation to the feed water; but that no dependence can be placed on them

will be evident from a glance at Mr. D. Croll's paper (Transactions of the Institution of Naval Architects, 1894, Vol. XXXV, page 425), in which, out of seven engine trials, the indicator cards only accounted for from 90 to 67 per cent. of the total steam. In the full power trials of the Research Committee on Marine Engines Trials, which lasted many hours, the variations are even greater, as will be seen from Table II., and in the exhaustive trials which were made by Professor Osborne Reynolds, F.R.S. (Proceedings Inst. Civil Engineers, Vol. XCIX, p. 194), similar results are obtained. See Table III.

TABLE II.

Proceedings Mechanical Engineers. Year and page.	Vessel.	Feed water per hour. 1892, p. 160–1.	High pressure cylinder after cut-off.	Mean pressure cylinder at 0.6 stroke.	Low pressure cylinder before release.
		Lbs.	*Per cent.*	*Per cent.*	*Per cent.*
1890, p. 211	*Fusi Yama*	7,860	16.9	...	29.2
1890, p. 223	*Colchester*	43,020	28.0	...	47.3
1890, p. 235	*Tartar.**	21,564	54.8	50.9	39.7
1891, p. 215	*Iona.**	8,616	36.6	25.1	40.9
1892, p. 155	*Ville de Douvres*	66,180	19.4	...	27.5

* NOTE.—The jacket water is included.

TABLE III.—MOISTURE IN STEAM. ESTIMATED FROM INDICATOR CARDS AT MID STROKE. EXPERIMENTAL ENGINE, OWENS COLLEGE, MANCHESTER.

High pressure cylinder.		Mean pressure cylinder.		Low pressure cylinder.	
Revolution.	Moisture.	Revolution.	Moisture.	Revolution.	Moisture.
146	39 per cent.	127	34.5 per cent.	109	48 per cent.
229	27 "	215	34 "	184	47 "
322	21 "	320	27 "	276	36 "

It is also a matter of everyday experience, that the steam weights estimated from indicator cards of different cylinders of the same engine rarely agree, and nobody should be surprised to find that the feed water measurements obtained by me during very short trials, differ from the indicator card readings. The

results of the experiments which are detailed in Tables IV and V, Engines A and B, cannot therefore be looked upon as proving the accuracy of the method, but have been included here as an illustration of the simplicity of its working; and even if these estimates are not accepted as being absolutely correct, they are certainly of relative value, being made under identical conditions, and they therefore throw some light on the question of economy of working when the engines are linked up or when the steam is throttled. In experiment No. 1, Table IV, the salinity of the feed water is perhaps too low, the injection having been started only five minutes before sampling, and the estimated volume of condensed steam and the moisture in the cylinders would be too high. In both these engines much trouble was experienced with the high pressure indicator, and in experiment No. 1 there is some doubt as to whether the number of revolutions should not have been 88 instead of 80.

The method of carrying out these experiments was as follows: A small india rubber hose was connected to a sea cock X, Fig. 1, and supplied sea water to the graduated glass jar J; a pipe P, capable of withstanding an internal vacuum, was led from the bottom of the jar J to a special cock A under the air pump (the brine cock B was used in some cases and would do equally well). Both the cocks X and A were kept open for about five or ten minutes before each experiment, so that a small but steady flow of water from the sea took place, passing through the condenser into the feed pumps, from which a sample was now taken at the cock C. A sample of sea water was also collected, and the cock X was then closed, care being taken to see that the jar J was full of water. The suction to the condenser being still open, the water level in J would sink, and the rate of injection could easily be ascertained by noting the times at which the various marks on J were being passed. The actual readings for the four experiments on engine A are given in Table VI.

The collected samples were now chemically analyzed, as will be explained later on, and the estimate of the volume of condensed steam was then a simple matter. Thus in the case of experiment No. 1, Table IV, it was found that the sample of

TABLE IV.—ENGINES A, 18 INCHES AND 36 INCHES DIAMETER, 24 INCHES STROKE.

	1	2	3	4
Reference number	1	2	3	4
Conditions under which the engines were worked	Linked up.	Throttled.	Throttled.	Throttled.
Time of commencing to inject sea water into the air pump	12·21 p. m.	12·21 p. m.	12·21 p. m.	12·21 p. m.
" " collecting samples of water and taking indicator cards	12·26 p. m.	12·34 p. m.	12 41 p. m.	12·49 p. m.
Steam pressure ..... lbs. per sq. in.	102	98	100	110
Receiver pressure ..... " " " "	2	2	2	1
Vacuum ..... inches.	27¼	26½	26	26¼
Revolutions per minute	80	84	98	73
Indicated horse-power	Spoilt.	152	237	99
Steam weights, estimated from high pressure indicator cards ... lbs. per hour.	...	2,575	4,110	2,220
" " " " low " " " ... " " "	2,336	3,217	4,622	2,198
CHEMICAL DETERMINATIONS.				
Salinity of feed water samples (see Table XI) ..... grains per gallon.	63·3	70.2	72.9	87.9
" " sea " " (see Table XI) ..... " " "	1,963	1.974	1,960	1,980
Measured volume of sea water injected into air pump (see Table VI) gallons per hour.	12.68	12.62	19 72	11.70
Estimated volume of condensed steam ..... " " "	380.5	342 5	510 47	251.6
" weight of condensed steam per indicated horse-power. lbs per hr.	Spoilt.	22 5	21.5	25 4
" moisture in high pressure cylinder ..... per cent.	...	24 9	19.5	11.8
" " " low " " ..... " "	38.6	6.2	9.5	12.3

The indicator cards of these trials are not satisfactory.

TABLE V.—ENGINES B, 15 INCHES, 25½ INCHES AND 41 INCHES DIAMETER, 27 INCHES STROKE.

	5	6	7	8	9
Reference number					
Conditions under which the engines were worked	Throttled.	Linked up	Full speed.	Full speed.	Full speed.
Time of commencing to inject sea water into the air pump	9·26 a. m.	9·43 a. m.	1·16 p. m.	1·48 p. m.	4·19 p. m.
" " collecting samples of water and taking indicator cards	9·36 a. m.	9·53 a. m.	1·26 p. m.	1·58 p. m.	4·29 p. m.
Steam pressure ..... lbs. per sq. in.	142 to 116	120	159 to 142	160	150
No. 1 receiver pressure ..... " "	1	24½	49½	51	45
No. 2 " " ..... " "	—7½	—4	4½	4½	4¾
Vacuum ..... inches	24	26	25	22	24½
Revolutions per minute	46	56	102	101	100
Indicated horse-power		High-pressure cards spoilt.			553
Steam weights, estimated from high pressure indicator cards, lbs. per hour		" "	" "		8,140
" " " " mean " " " "	1,302	1,287	8,709	Spoilt.	7,878
" " " " low " " " "	1,617	1,302	7,050	7,080	6,610
CHEMICAL DETERMINATIONS.					
Salinity of feed water samples ..... grains per gallon	85.9	86.0	21.2	19.9	22.7
" " sea " " ..... " "	1,750	1,728	1,977	1,892	1,877
Measured volume of sea water injected into air pump, gal. per hr.	10.84	10.78	10.71	9.86	10.78
Estimated volume of condensed steam ..... " "	210.0	205.3	988.0	927.7	880.6
" weight of condensed steam per ind. horse-power, lbs. per hour	...	...	...	...	16.2
" moisture in high pressure cylinder ..... per cent	...	...	...	...	7.5
" " " mean " " ..... "	38	37·5	11.8	...	10.5
" " " low " " ..... "	23	36.7	28.6	23.6	25.0

feed water contained 63.3 grains of salt per gallon, while the sea water contained 1,963 grains. The rate at which the condenser sucked the sea water out of the jar J was 12.68 gallons per hour (see Table VI), and therefore the amount of steam condensed per hour was $12.68 \times (1{,}963 - 63.3) \div 63.3 = 380.5$ gallons, as stated in Table IV.

Generally speaking, the process is somewhat more complicated, because of possible leakages of the condenser, and priming. To estimate these, preliminary samples of feed and boiler water have to be collected before the injection is commenced. If the former are found to contain salt, corrections must be made which, although they are simple enough, introduce some uncertainty into the calculations, because one cannot depend on the leakages or priming being constant. All experiments with sea water in which any leakage was detected have been rejected, but in every case samples were taken both before and after starting to inject, in order to be sure that there was no leakage.

MEASUREMENT OF FEED BY CAUSTIC SODA INJECTIONS.

For this reason, and also because of the possibility which presented itself of also measuring the volume of circulating water, other experiments were made, in which the chemicals injected were, in one case caustic soda, and in another trial, carbonate of soda. The results of the caustic soda trials are given in Table VII, engine C, trials 10 to 14. Two jars were used on the trial, one for supplying the condenser and one for the circulating pump, but this arrangement did not work well except as regards the feed, for which the injected solution amounted to less than three gallons per hour. The supply to the circulating pump could not be maintained at a constant rate, because the jar had to be constantly refilled by jugs, which left no time for accurate observations. During these trials, which lasted about two hours, the caustic soda solution took the skin off all my finger tips, and when carrying out the chemical determinations difficulties arose on account of precipitates being formed both in the feed and circulating water samples; it also interferes with the salt test, so that this chemical cannot be recommended for general use.

TABLE VI.—TIME READINGS AND JAR MEASUREMENT DURING THE TRIAL OF ENGINE A. (SEE TABLE IV.)

Reference Number.	1.	2.	3.	4.
Mark on Jar.	Seconds.	Seconds.	Seconds.	Seconds.
0.65 gallons.	0	41½	39	...
0.6 "	13½	55½	47½	...
0.55 "	27	70	57	12½
0.5 "	40½	83½	66	29
0.45 "	55	98	75	45
0.4 "	69	111½	84	52
0.35 gallons.	83½	126	92½	69
0.3 "	97	140½	102	84
0.25 "	111½	154½	112	108
0.2 "	127	169	120½	124
0.15 "	141½	184	130	...
0.1 "	155	199	140	...
Sum of reading 0.65 to 0.4.....	205	460	368½	138½
" " 0.35 to 0.1.....	715½	973	697	385
Difference.....	510½	513	328½	246½
Gallons per hour (see Table IV).....	12.68	12.62	19.72	11.70

The results of this trial have been recorded because they were very carefully made, and the information thus gained may be of value. In this case the indicator cards were all satisfactory.

MEASUREMENT OF CIRCULATING WATER BY SODA INJECTIONS.

One of the objects of measuring the circulating water was to obtain a check on the feed water estimate, which could be done by comparing the heat contained in the steam when it leaves the low pressure cylinder, with the heat which is carried overboard by the circulating water. The exact amount of heat which is thus wasted has not yet been calculated, but it is evidently less than that contained in the steam when it enters the low pressure cylinder, but it may be more than the heat contained in the steam at its exhaust temperature. Reckoning from 32° Fahrenheit these two limits are about 1,150 and 1,130 thermal units. The

TABLE VII.—ENGINES C, 18 INCHES AND 40 INCHES DIAMETER, 27 INCHES STROKE.

	10	11	12	13	14
Reference number					
Conditions under which the engines were worked	Throttled.	Full speed.	Linked up.	Linked up.	Throttle shut.
Time of commencing to inject caustic soda brine into the air pump	12·6 P. M.	?	1·4 P. M.	1·24 P. M.	2·26 P. M.
" collecting samples of water and taking indicator cards	12·12 P. M.	?	1·10 P. M.	1·30 P. M.	2·32 P. M.
Steam pressure, lbs. per sq. in.	124	115	102	92½	90
Receiver pressure, " "	5½	10	9	8	1
Vacuum, inches	25½	25	28	27	26
Revolutions per minute	98	101	88	80	74
Indicated horse-power	329	477	254	214	182
Steam weights, estimated from high pressure indicator cards, lbs. per hour	5,260	7,200	3,860	3,170	2,680
" " " low " " " "	5,730	7,610	3,895	3,300	2,390
CHEMICAL DETERMINATIONS.					
Alkalinity of feed water samples, milligrams per 100 c.c.	43.62	29.77	51.60	53 75	59.38
" " " " "	43.98	30.23	51.48	53 72	58.82
Mean values " "	43.80	30.00	51.54	53.735	58.60
Alkalinity of caustic soda brine diluted in distilled water (see Table X), milligrams per 100 c.c.	8,820	8,820	8,820	8,820	8,820
Measured volume of caustic soda brine injected into air pump, gallons per hour	3.11	2.845	3.002	2.830	3.145
Estimated volume of condensed steam " "	623.2	833.6	510 8	461.7	470.2
" weight of condensed steam per indicated horse power, lbs. per pound	18.9	17.5	20 1	21.6	25.8
" moisture in high pressure cylinder, per cent	15.8	13.8	24.7	31.5	43.0
" " low " " "	8.3	8.9	24.0	28.7	49.2

moisture contained in the steam ought, perhaps, only to be credited with from 130 to 200 thermal units, unless the whole phenomena of moisture in the cylinders can be explained by initial condensation and final re-evaporation, in which case the total feed water (which includes the moisture), if cooled down to 32° Fahrenheit, may be assumed to have parted with about 1,140 thermal units.

No experiments on this subject have been made on marine engines, and as regards land engines the feed and condensing water are rarely kept separate; and being mixed, they have to be measured together, and even when surface condensers have been used, only the feed which is supplied to the boiler, and not the condensed steam which leaves the engine, has been determined. The mechanical means employed for measurement are generally tanks for the feed, and overflow weirs for the discharge water. Professor Osborne Reynolds carried out a large number of trials on his triple-expansion engine (Proceedings Inst. Civil Engineers, Vol. XCIX, p. 194), in which the above mentioned quantities are recorded. The results are given in Table VIII. The

TABLE VIII.—EXPERIMENTAL DETERMINATION OF THE AMOUNT OF HEAT REJECTED PER POUND OF STEAM USED IN THE EXPERIMENTAL TRIPLE-EXPANSION ENGINE AT OWEN'S COLLEGE, MANCHESTER.

Condition of working engine.....	Jacketed.			Unjacketed.		
Number of trial.....	44	33	56	41	35	40
Heat carried away by the circulating water per pound of steam condensed, thermal units.....	1,076	1,043	1,042	1,064	1,001	979
Temperature of hot well above 32° Fahrenheit, degrees Fahr.....	70	82	81	76	82	100
Observed total heat contained in one pound of steam above 30° Fahrenheit, thermal units.....	1,146	1,125	1,123	1,140	1,083	1,079
Excess of observed heat over estimated heat, thermal units.....	+64	+29	+31	+51	—8	—12
Excess of observed heat over estimated heat, per cent.....	+5.6	+2.6	+2 7	+4.4	—0.7	— 1.1

excess temperature of the feed over the freezing point of water has been added by me, in order to make the readings comparable with my determinations. The last line of this table contains the differences between Professor O. Reynolds' experiments and his estimates, but I am unable to say how the latter were obtained. The point to which particular attention should be directed is the variation amongst the results; thus the highest and lowest values for the jacketed engines differ by 3.0 per cent., and those for the unjacketed engines differ by 5.5 per cent.

On referring to my last trials, recorded in Table IX, engine D, Nos. 15 to 18, last line, it will be seen that the observed amounts of heat rejected per pound of feed water were, 1,176.5, 969, 1,037, 1,120. The first value, No. 15, may be slightly high, for although both injection cocks were opened at 3·52 P. M., the one which supplied the circulating pump was accidentally closed again until 4·10 P. M., while that for the feed was full open all the time. The error cannot be a serious one, because it takes only fifteen double strokes of the circulating pump to fill all the water spaces of the condenser. (See Condenser Section, Fig. 2.) The engine having accidentally been stopped between Nos. 15 and 16, it is reasonable to assume that water had accumulated in the cylinders, which accounts for the low results in Nos. 16 and 17 and perhaps even No. 18: the latter was measured about twenty minutes after re-starting. As these experiments (Table IX) may be considered entirely successful, the following detailed description of the proceedings will be of interest.

A large tank T which is partly shown in section, Fig. 3, was placed near the pumps. It was filled with two hundred-weight of washing soda, and hot water, and very thoroughly mixed, as was proved by chemical analysis of five samples, taken at 3·52, 4·32, and 4·50 P. M. (see Table X). A wooden float F, was laid on the brine, and a light wooden gallows *g* secured to it. This supported two india rubber tubes *m* and *n*, whose ends, which were bent glass pipes of $\frac{1}{4}$-inch and $\frac{1}{8}$-inch diameter, were thus always kept at a definite distance below the fluid level, F, in the tank, whereby a very constant flow was secured. The other end of the tube *m* was connected to a $\frac{5}{8}$-inch cock *c*, at the bottom of

TABLE IX.—ENGINES D, 15, 25½ AND 41 INCHES DIAMETER, 27 INCHES STROKE.

		Trial No. 1.	Trial No. 2		
Reference number		15	16	17	18
Time of commencing to inject carbonate of soda brine		3'52 p. m.	4'32 p. m.	4'32 p. m.	4'32 p. m.
" " collecting samples of water, and taking indicator cards		4'10 p. m.			
		4'15 p. m.	4'37 p. m.	4'42 p. m.	4'47 p. m.
Steam pressure	lbs. per square inch.	160	145	...	...
No. 1 receiver pressure	" " " "	58	48	No cards.	No cards.
No. 2 receiver pressure	" " " "	8	6	"	"
Vacuum	inches.	16¼	27	"	"
Revolutions per minute		103	101	"	"
Indicated horse-power		629.6	588.3	"	"
Steam weights, estimated from high pressure indicator cards	lbs. per hour.	7,800	7,460	"	"
" " " " mean " " "	" " "	9,010	8,810	"	"
" " " " low " " "	" " "	8,060	7,710	"	"
CHEMICAL DETERMINATIONS. SEA WATER.					
Alkalinity of circulating water samples, collected at discharge valve Y (Fig. 3)	milligram per 50 c.c.	6.61	7.12	6.73	6.84
	" " " "	6.53	7.14	6.89	6 68
	" " " "	6.59	...	6.95	6.76
Mean values	" " " "	6.577	7.13	6.92	6.72
Alkalinity of circulating water samples, collected at condenser top X (Figs. 2, 3)	" " " "	7.03	7.25	6.85	6.84
	" " " "	6.98	7.29	6.82	6.97
	" " " "	6.97	7.20	...	6.91
Mean values	" " " "	6.993	7.247	6.835	6.94
Alkalinity of sea water samples, collected at ash cock	" " " "	2.89	2.88	2.55	2.92
	" " " "	2.86	2.79	2.62	2 82
	" " " "	...	...	2.61	2.84
Mean values	" " " "	2.875	2.835	2.593	2.83
Alkalinity of sea water due to injected brine. Difference of two last mean values	" " " "	4.118	4.412	4.242	4.11
" " " carbonate of soda brine when diluted with sea water (see Table X)	" " " "	2,975	2,975	2,975	2,975
Measured volume of carbonate of soda brine injected into circulating pump	gallons per hour.	30.18	30.82	30.22	29.62
Estimated volume of circulating water	" " "	21,770	20,750	21,170	21,410

TABLE IX.—(Continued.)

	Trial No. 1.	Trial No. 2.		
Reference number	15	16	17	18
Time of commencing to inject carbonate of soda brine	3'52 P. M. / 4'10 P. M.	4'32 P. M.	4'32 P. M.	4'32 P. M.
" " collecting samples of water and taking indicator cards	4'15 P. M.	4'37 P. M.	4'42 P. M.	4'47 P. M.
CHEMICAL DETERMINATIONS. FEED WATER.				
Alkalinity of feed water samples	milligrams per 50 c.c.	4.16	3.85	4.29	4.76
" " "	" " "	4.27	3.75	4.31	4.91
" " "	" " "	.....	3.79	4.32	5.00
Mean values	" " "	4.215	3.77	4.315	4.955
Salinity of feed water samples	grains per gallon	178.0	6.1	1.5	0
Salinity of sea water	" "	1,972	1,943	.....	.....
Estimated percentage of supplementary feed water from sea	per cent.	9.94	0.31	0.08	0
" alkalinity of feed water due to supplementary feed	milligrams per 50 c.c.	—.1328	—.00415	—.00103	0
Alkalinity of feed water due to injected brine	" " "	4.348	3.811	4.316	4.955
Alkalinity of carbonate of soda brine when diluted with feed water (see Table X)	" " "	2,947	2,947	2,947	2,947
Measured volume of carbonate of soda brine injected into air pump	gallons per hour	1.437	1.323	1.322	1.321
Estimated volume of condensed steam	" " "	972.5	1021.7	901.4	784.5
" weight of condensed steam per indicated horse-power	lbs. per hour	15.4	17.4	.....	.....
Estimated moisture in high pressure cylinder	per cent.	18.4	25.7	.....	.....
" " mean " "	" "	5.5	12.3	.....	.....
" " low " "	" "	15.6	23.2	.....	.....

THERMOMETER READINGS.

Feed water	degrees	Fahrenheit	119.3	108.5	107.2	95.0
Circulating water condenser top X (Figs. 2, 3)	"	"	99.2	88.0	86.0	84.3
" " discharge valve Y (Fig. 3)	"	"	95½	89½	88	85½
" " condenser bottom Z (Figs. 2, 3)	"	"	45.9	45.7	45.9	45.7
Increase of temperature of circulating water	"	"	49.6	43.8	42.1	39.8

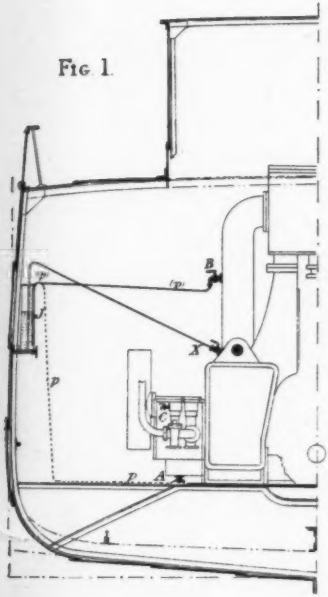
DISCHARGED HEAT.

Heat discharged by total feed water (including supplementary feed) above 32° Fahrenheit	thermal units		933,380	784,020	678,390	494,230
" " circulating water (the thermal capacity of sea water is 0.973)	"	"	10,507,820	9,116,230	8,669,470	8,291,490
Total heat discharged	"	"	11,441,200	9,900,250	9,347,860	8,785,720
" " " per 1 pound of feed water	"	"	1,176.5	969.0	1,037.0	1,120.0

the tank, and *n* ended in a brass tube syphon pipe *s*, whose lower end was placed at exactly the same height as the cock *c*, so as to ensure that the same quality of brine should be supplied to both. The result was satisfactory (see Table X). Samples No. 2 and 4 were taken from *n*, while Nos. 1, 3 and 5 came from *m*. The quantity of water which flowed out of either tube was measured as follows: For *n*, a glass flask was used; it had a funnel mouth (Fig. 4), and was carefully graduated up the neck, the lower reading being 100 cubic centimeters, or about 4 ounces, and the upper reading 105 cubic centimeters. It required about one minute to fill this flask. In order to measure the water which flowed out of *m*, a one-gallon tin was altered, as shown in Fig. 5, by having a funnel mouth soldered to its neck, of which the inside was graduated. The lowest mark was 5,020 cubic centimeters, and the highest 5,070 cubic centimeters. It took about two minutes to fill this tin. In either case the contents of the flask or jar could be read off to within one-tenth per cent. of the total volume, and the time of filling could be read off to within one-fifth second, so that the maximum error of these measurements could not exceed $\frac{1}{4}$ per cent.

During the first experiment of this last trial, the cock *c* was accidentally closed, which was not discovered until five minutes before taking the samples of trial No. 15, and then unfortunately the engines were unexpectedly stopped by the captain. In the second experiments, Nos. 16, 17 and 18, the rates at which the brine flowed out of *m* and *n* were determined before starting and after ending; they were 30.52 and 1.323 gallons per hour at the commencement, and 29.92 and 1.321 at the completion of the experiment. The slight change in the flow was due to a gradual but perfectly marked tilting of the float F, and could in future be guarded against. The measurements were made by holding either the flask or the gallon tin under *n* or *m* and noting the exact time of filling, and then removing them suddenly; the brine would then pour into the two funnels *p* and *r*, which were connected by $\frac{5}{8}$ and $\frac{1}{4}$-inch lead pipes, respectively, to the shifting valve V of the circulating pump, and to a cock A under the air pump, the latter being opened only very slightly, so as not to

Fig 1.



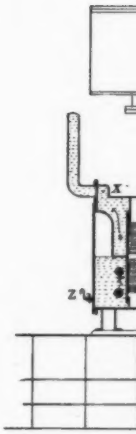


Fig 2

Fig 5

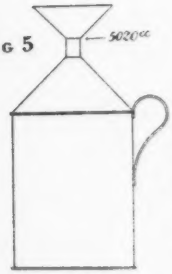
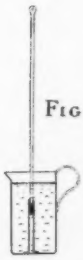


Fig 4

Fig



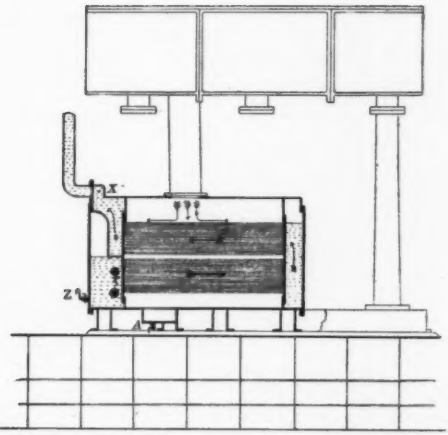


Fig 2

Fig. 3.

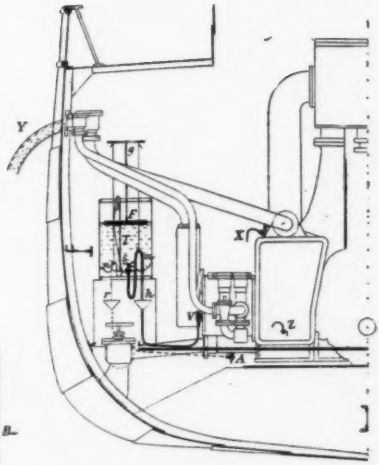


Fig 6.

Fig 7.

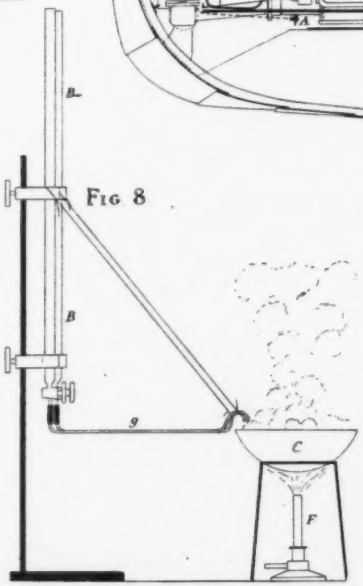


Fig 8

admit an unnecessary amount of air. As soon as the experiment was completed, the flask and tin were once more held under the tube ends of *m* and *n*, and new determinations of the rate of flow were made.

Water meters have unquestionably been brought to a high state of perfection, but none give correct readings if air should get mixed with the water, as is sure to be the case in a marine engine, unless the feed pump is worked automatically, and unless the circulating pump is driven by a separate engine. In my experiments, however, the trouble to be expected with a meter, if used for measuring the flow of brine, was not that air would get into it, but that its frictional resistance would produce an irregularity in the supply. In fact, the only practical plan of using a meter would be to couple it to the engine, and thus drive the brine into the feed or circulating water, making the necessary allowances for leakages.

The sampling of the various waters was done with the greatest care. One sample was taken from the ash cock after first thoroughly clearing the pipe, another was taken slowly from the feed pump. Two samples were taken of the circulating water, one from the cock X (Figs. 2 and 3) on the condenser top, the other was caught up by a bucket at the discharge valve Y. Apparently one sample would have sufficed, but as the water at Y had to be collected by swinging a bucket into the descending stream, there was a possibility of catching a portion containing either too much or too little brine, because, on account of the intermitted action of the circulating pump, and its large volume as compared with the condenser spaces, one might expect slight irregularities in the distribution of the brine *along* the stream, which would disappear in a sample collected slowly at X. As regards the discharge water temperatures, the conditions are evidently reversed; the irregularities are not likely to be found *along* the stream, but *across* its section, and the cock X might occupy a position where it would draw off only that water which has passed through the top rows of tubes, and which would naturally be the hottest, or it might draw off a colder stream. However, when these various streams have passed through the

TABLE X.—CHEMICAL DETERMINATIONS OF THE ALKALINITY OF THE BRINES USED IN EXPERIMENTS C AND D.

Engine C (See Table VII).

Caustic soda brine diluted in—

Distilled water.

Sample volumes.		Alkalinity.		
Distilled water.	Brine.	Observed.	Mean value.	Difference.
c.c.	*c.c.*	*m. g.*	*m. g.*	*m. g.*
100	0.1	8.88	8.82	+.06
100	0.2	17 60	17.64	—.04
100	0.3	26 50	26.46	+.04
100	0.4	35.28	35.28	0
100	0.5	44.07	44.10	—.03
100	0.6	53.00	52.92	+.08

Mean, 8,820 milligram per 100 c.c.

Sea water.

Sample volumes.		Alkalinity.		
Sea water.	Brine.	Observed.	Mean value.	Difference.
c. c.	*c. c.*	*m. g.*	*m. g.*	*m. g.*
100	0	5.45	5.45	0
100	0.1	14.32	14.31	+.01
100	0.2	23.16	23.17	—0.1

Mean, 8,860 milligram per 100 c. c.

Engine D (See Table IX).

Carbonate of soda brine diluted in—

Distilled water (various samples)

Sample number.	Sample volumes.		Alkalinity.		
	Distilled water.	Brine.	Observed.	Mean value.	Difference.
	c. c.	*c. c.*	*m. g.*	*m. g.*	*m. g.*
1	50	0.1	5.78	5.78	0
1	50	0.1	5.76	5.78	—.02
2	50	0.1	5.74	5.78	—.04
2	50	0.1	5.80	5.78	+.02
3	50	0.1	5.90	5.78	+.12
3	50	0.1	5.76	5 78	—.02
4	50	0.1	5.80	5.78	+.02
4	50	0.1	5.74	5.78	—.04
5	50	0.1	5.82	5.78	+.04
5	50	0.1	5.75	5.78	—.03

Mean, 2,890 milligram per 50 c. c.

Feed water (Sample No. 1).

Sample volumes.		Alkalinity.		
Feed water.	Brine.	Observed.	Mean value.	Difference.
c. c.	*c. c.*	*m. g.*	*m. g.*	*m. g.*
50	.....	.06	.06	0
50	.....	.05	.06	—.01
50	0.03	1 81	1.78	+.03
50	0.03	1 81	1.78	+.03
50	0.06	3 58	3.59	—.01
50	0.06	3 58	3 59	—.01
50	0.09	5.35	5.36	—.01
50	0.09	5.37	5.36	+.01

Mean, 2,947 milligram per 50 c. c.

Sea water (Sample No. 1).

Sample volumes.		Alkalinity.		
Sea water.	Brine.	Observed.	Mean value.	Difference.
c. c.	*c. c.*	*m g.*	*m. g.*	*m. g.*
50	.....	2.75	2.77	—.02
50	.....	2 85	2 77	+.08
50	0.02	3.95	3.96	—.01
50	0.02	3.98	3.96	+.02
50	0.04	5.16	5.16	0
50	0.04	5 27	5.16	+.11
50	0.06	6.27	6.35	—.08
50	0.09	7.50	7.54	—.04

Mean, 2,975 milligram per 50 c. c.

discharge valve, they will be well mixed, and by swinging the bucket into the full stream at Y a fair average temperature sample would be obtained. These views are fully confirmed by the chemical and thermometric readings of both sets of samples, which are all recorded in Table IX, but have not all been used in the subsequent calculations.

In order that these temperatures might be read off with the greatest care, four tin plate quart pots were fitted with small split tubes, see Fig. 6, into which the thermometers were inserted; any danger of cooling the thermometer while taking its reading was thereby removed. The water in each quart pot was then poured into a bottle and subseqently analyzed. All the thermometers had been compared and their readings corrected. The divisions were sufficiently large to allow of tenths of degrees Fahrenheit being read off, but this was not done for the samples collected at Y. The temperature of the sea was read off from a sample collected at the condenser bottom cock. The samples for Nos. 16 to 18 were taken in the River Clyde, between Gourock and Greenock.

CHEMICAL DETERMINATIONS. I. SALT TESTS.

In the experiments which have been detailed in Tables I, IV, and V, the nitrate of silver test for salt was used. A large stock solution was prepared of nitrate of silver and distilled water (about 120 grains to the gallon), from which the accurately graduated burette B, Fig. 7, was replenished. The sample of water to be tested was poured into the beaker A, to which a few drops of a strong solution of yellow chromate of potash had been added. All the sea water samples were first diluted down to the strength of the salted feed water. A reading was now taken of the upper level of the nitrate of silver solution, of which as much was then run into the beaker as would just cause the sample to change its color from a pale yellow to a reddish brown. With a little practice this could be done with the greatest nicety, as is shown by the readings of the salinity of Glasgow town water, in which there were only 1.3 grains of salt per gallon. The change of color could not be read with the same precision when there

were larger percentages of salt, because of a heavy milk precipitate of silver chloride. Table XI contains the actual readings of the chemical tests for engine A (Table IV). In no case do they differ by more than $\frac{3}{4}$ per cent. from the mean values. For fairly accurate and rapid determinations this test cannot easily be surpassed, but in inexperienced hands there is always a danger of obtaining too high a reading, because the change of color must have taken place before it is noticed. To minimize this danger, the sea water samples were diluted down to the strengths of the feed waters with which they had to be compared. The error of 5 per cent. in Table I, if it is not due to leakage as ex-

TABLE XI.—BURETTE READINGS OF THE NITRATE OF SILVER TEST ON EIGHT SAMPLES OF WATER FOR ENGINE A, TABLE VI.

	Sea water.				Feed water.			
Reference number	1	2	3	4	1	2	3	4
Volumes tested	*c. c.* 2×1	*c. c.* 2×1	*c. c.* 2×1	*c. c.* 2×1	*c. c.* 4×10	*c. c.* 4×10	*c. c.* 4×10	*c. c.* 4×10
Burette readings	2.95	1.80	2.00	2.05	2.50	0.25	1.90	1.75
Burette readings	68.00	66.95	66.85	67.55	23.15	23.60	25.80	31.20
Burette readings	0.00	4.55	1.35	3.85	44.15	46.75	50.00	60.40
Burette readings	64.75	70.05	66.10	69.25	65.10	69.90	74.40	89.40
Mean values	64.90	65.27	64.80	65.45	20.90	23.20	24.17	29.02
Grains of salt per gallon	1,963	1,974	1,960	1,980	63.3	70.2	72.9	87.9

plained, may be put down to this cause, for it only amounts to 0.065 grains per gallon, which would affect the burette readings by only 0.025 cubic centimeters.

Mr. Volhardt's Method.—A more accurate test for salt is the following: Prepare a weak aqueous solution of nitrate of silver and nitric acid, also a weak solution of sulphocyanate of ammonia: the two fluids should be of equal strengths. A preliminary determination of the salinity of a small portion of the sample is made as described, then a carefully measured volume of the sample is mixed with a carefully measured volume of nitrate of silver solution, but slightly more than required, so as to precipitate all the chlorides. This sample is put aside for a day in a dark

place, and the clear fluid is drawn off and tested with the help of the above standard solutions. A drop or two of ferric alum salt index is first added, and then the sulphocyanate is titrated into it out of the burette until a change of color takes place. If this is too marked, a little nitrate of silver solution is added, and this zigzag titration continued until the neutral point has been reached. The differences of the readings of the two burettes are then subtracted from the volume of nitrate originally added to the sample, and the remainder is the exact volume of the weak nitrate of silver which was required to neutralize the salt in the sample. Both the above named tests ought to be carried out by artificial light. The clearing is not necessary with weak salt waters.

II. ALKALI TEST.

Many substances are known which change color if transferred from an acid bath into an alkali one, but for the determination of alkalinity of sea water nothing is likely to surpass aurine as an index, if used as recommended by Mr. Tornö.

Weak solutions of hydrochloric acid and water, and of caustic soda and water are prepared, the two being made exactly equal in strength. They are poured into two burettes (B, Fig. 8). A carefully measured volume of the water sample to be tested is poured into the Berlin bowl C, a few drops of aurine, dissolved in water, are added, and the whole is then boiled over a Bunsen burner F. The color of the fluid will at once change from an imperceptible pale amber to a beautiful rose pink; measured quantities of hydrochloric acid are from time to time added from the burette until the rose color has permanently disappeared, which is a sign that the hydrochloric acid is in excess. Boiling is necessary in order that all the carbonic acid in the sea water, both free and combined, may be driven out. Drop by drop, alkali solution is now added until the pink color returns, then acid is added until it just disappears. The difference of the loss of solution from the two burettes is a measure of the alkalinity of the sample. A second sample from the same bottle is now measured out, and a slight excess (about 1 per cent.) of acid solution is added, the boiling is proceeded with for about fifteen

minutes, and then the neutralization is effected as before. If this determination did not agree with the first one, I took another sample and rejected the first. All the actual readings are recorded in Tables VII, IX and X. In the first experiments, Table VII and part of Table X, several precautions had been omitted, and these results are, therefore, not as uniform as they might have been.

During the progress of these tests, it was frequently noticed that the levels of the fluids in the burettes had changed, once even as much as .15 c. c., although no fluid had been drawn off. This was found to be due to the gradual heating of the fluid in the burrette on account of its proximity to the Bunsen burner. To remove the burettes after each slight addition would have been troublesome, and might, during the fifteen minutes of boiling, have led to an occasional loss of a drop of acid or alkali, which would have affected the results by 1 per cent. The final arrangement adopted was that shown in Fig. 8, in which a long, fine glass tube *g* reached from each burette to the Berlin bowl.

The strengths of the acid and alkali solutions were those adopted by the late Professor W. Dittmar, viz., each cubic centimeter contained as much caustic soda as would exactly neutralize 1 milligram of carbonic acid. These are the units adopted in the tables. Experiments which were subsequently carried out by me, with solutions having only one-tenth of the above strength, proved that a change of color of the aurine index was quite perceptible on adding only .01 cubic centimeter of the standard fluid, a quantity which affected the levels in the burettes by less than $\frac{1}{400}$ inch. However, having commenced the chemical determinations before I was fully aware of this extraordinary accuracy, I did not venture to dilute the fluids, and all the readings are made with the normal strengths.

A still more accurate determination than any to be found in this paper could have been made, if, instead of salt or soda, the rather expensive chemical, nitrite of soda, had been injected into the waters. The accuracy attainable with this substance is such, that the capacity of one of the Tilbury graving docks, holding about 60,000 tons of water, could be determined chemically to

within 1 per cent. of its true amount, if only one hundred-weight of nitrite were to be dissolved in the water, of which a few ounces would suffice for the analysis, which is a colorimetric one. The experiment would cost about £20.

With the experience that had been gained by sea injections into feed water to guide me, I was afraid that soda solutions would produce chemical changes that might interfere with my tests; and, in order to be quite independent of such influences, the brines which were used have been chemically tested when diluted down to the experimental strengths, either with feed water or with sea water (see Table X), and the results have been used as standards of comparison in Table VII and IX. The tests on mixtures of feed water, and brine sample No. 1, are carried out with every conceivable precaution, except that the titrating fluids were not diluted, and are, as will be seen, highly satisfactory. It will be noticed that in Table IX a separate chemical determination of the salinity of the feed water has been made; this was only possible when using carbonate of soda brine injection, but was necessary because of the supplementary feed being partly open until 4·15 P. M. As will be seen, the sea water thus introduced had not been entirely washed out even after half an hour's run. For this reason several of my experiments, based only on the salt test, have not been included in this paper, for I could not feel sure as to whether the detected leakages were real ones.

A notice will be found in Table IX that the thermal capacity of sea water is 0.973. No direct experiments on the subject seem to have been made, but I discovered some by Mr. Schüller (Poggend. Ann., Vol. CXXXVI) on the specific heats of salt solutions, from which the above value has been estimated. The specific heat of chloride of soda is 0.21401, and the density of sea water has been assumed to be 1.026.

CONCLUSIONS.

Having demonstrated the accuracy of this chemical method of estimating water quantities, it only remains to point out the advantages which can be obtained by its use.

(1) The circulating water of a marine engine can be measured at sea; this has not been done before. The quantity of carbonate of soda (washing soda) required is approximately two hundred-weight per 1,000 I.H.P. per hour, which should be dissolved in a tank of fresh water holding about 60 gallons.

(2) The feed water of marine engines (300 cubic centimeter samples should be collected), not fitted with slow working automatic pumps, can be measured either by injecting carbonate of soda brine or sea water. On account of the air which is mixed with the feed water, when the pumps are worked by the main engines, mechanical feed meters would not give accurate results under such conditions.

(3) The method can be applied to the accurate measurement of the volume of water in small streams, and would be of special value in a mountainous district. It being possible to determine the salinity of water, holding only one grain per gallon in solution, to within 1 per cent. of its true amount, it would be necessary to add salt brine (containing fifty ounces to the gallon) at the rate of only one gallon per minute to a stream which delivers 350 gallons of water per second, and to collect a sample after thorough mixing has taken place. The measurement of the volume of water supplied to towns for drinking purposes is frequently done by weir gaugings, which are said to be unreliable to the extent of 5 per cent.

In conclusion, I beg to thank Messrs. R. Napier & Sons, Messrs. Ross & Duncan, Messrs. Muir & Houston, Mr. C. M. Aikman, Mr. R. J. Beveridge, Mr. Sinclair Couper, Mr. D. Johnson, and Mr. J. Thom for their assistance during these experiments, which have now extended over a period of two years, and have entailed an amount of labor which is only faintly indicated by the five trials that have been submitted in this paper.

DEVELOPMENT IN DESIGN AND CONSTRUCTION OF GERMAN MEN-OF-WAR.

By Herr A. Dietrich, Wirklicher Geheimer Admiralitäts-rath, Constructor in Chief of the Imperial German Navy; Member.

[Read at the Summer Meeting of the Thirty-seventh Session of the Institution of Naval Architects, June, 1896.]

Thirty years ago only one shipyard in Germany was able to construct men-of-war adequate to the demands of the time, the Royal Prussian Dockyard at Danzig. At that time this yard was building the wooden screw frigate *Elizabeth*, and a short time later two ships for the newly formed North German Confederation, the *Undine*, a sailing brig for training purposes, and the armored screw corvette *Hansa* of 3,600 tons displacement; the last one was the first ironclad vessel ever built in Germany. The dockyard at Danzig was fitted out to build only wooden hulls, so the iron unarmored superstructures of this ship were built up by the Vulcan private dockyard at Stettin, the armor plates were ordered from England. In the year 1869, the first *iron* armor clad ever built in Germany, the turret ship *Grosser Kurfürst*, was commenced in Wilhelmshaven, where the new dockyard was not even nearly finished. The shipyard Vulcan in Stettin started shortly afterwards on the *Preussen*, a sister vessel of the *Grosser Kurfürst*. Work on these vessels could only be carried on very slowly during the time of the Franco-German war, so that the first *iron* armor clad built in Germany, the *Preussen*, could not be launched before November, 1873. Her sister ship, the *Friedrich der Grosse*, was launched in 1874 from the new Imperial Dockyard at Kiel. Owing to the unfinished state of the dockyard at Wilhelmshaven, and the very unfavorable conditions, the *Grosser Kurfürst* was not ready for launch before September, 1875, six years after work was commenced.

After the Franco-German war the Chief of the German Admiralty, General von Stosch, laid out a plan to build up the navy (Flottergründungsplan), according to which work was commenced, but is not quite finished at present, as not all types of ships have the intended number of vessels.

To get armor clads as quickly as possible, it was necessary to place orders abroad, since German shipyards were not efficient enough at that time. The two armored frigates, *Kaiser* and *Deutschland*, were built at Samuda's dockyard from the designs of Sir Edward Reed, and were launched in the year 1874. These two ships form still part of the German battle fleet, after having been constructed, as well as it was possible, to suit modern requirements. Since that time no German man-of-war of any considerable size has been built abroad, the German shipyards were in the meantime well fitted to execute all orders. Then those vessels were commenced which suited best the formation of the German coast. According to the building plan, four coast defence armorclads (Ausfall-Corvetten) of the *Sachsen* type were ordered, which, on a draught not exceeding 6 meters (19.68 feet), had to carry the heaviest armor of 16 inch thickness (Sandwich system), and an armament of six guns of 26 centimeters (10 inch) caliber. These ships are nearly the first armorclads ever constructed on the citadel type. The keel of the *Sachsen* was laid as early as 1874, and she was launched in 1877; the first citadel ships, the *Inflexible* and the *Duilio*, were launched in 1876. The last of the three sister ships of the *Sachsen* type, the *Baden*, was not launched till 1880.

Coast defence had to be considered before everything else, and, therefore, contemporaneously with the above mentioned vessels, work was commenced, not on monitors as at first planned, but on ironclad gunboats of the *Wespe* type. These boats, of 1,000 tons displacement, were plated with 8-inch (200-millimeter) armor, carried one gun of 12-inch (30.5 centimeter) caliber, and drew only 3 meters (9.84 feet). Eleven of these boats were built.

For a long time no armorclad was built in Germany except the *Oldenburg*, which was started in March, 1883, and finished in November, 1886. She was intended to be the fifth vessel of

the *Sachsen* type; but, owing to want of money, she had to be made smaller and of quite another type.

With the armorclad *Siegfried* a quite new type was started in 1887, also intended for coast defence only, and especially for the mouth of the river Elbe, on account of the construction of the Kaiser Wilhelm Canal.

Eight vessels of this type were built, but the two last, the *Aegir* and *Odin*, are somewhat different from the sister ships, being constructed after the citadel type ships. The main condition for these vessels also is the low draught, only 5.5 meters (18 feet). They carry, on a displacement of 3,500 tons, heavy ordnance, three 24-centimeter guns, arranged especially for defending river estuaries, and are armored with 240-millimeter ($9\frac{7}{16}$-inch) plates, and have a speed of 15 knots.

Thus, since 1873, three different types of armorclads, of 7,400 tons, 3,500 tons, and 1,000 tons were built for coast defence, each type designed and executed for this limited purpose.

The construction of seagoing armor clad battleships, which have to advance farther out, in order to defend the coasts more effectually, was not commenced before 1889, after a lapse of sixteen years. Then, however, four vessels of the same design were started simultaneously; these are the *Brandenburg*, *Weissenburg*, *Wörth* and *Kurfürst Friedrich Wilhelm*, of more than 10,000 tons displacement, a speed of 17 knots, 400 millimeters (15.75 inches) thickness of armor in the belt which surrounds the water line, and, in addition to a reduced light armament, six guns of 28 centimeters (11 inches) caliber in three revolving turrets.

Two still bigger ships, the *Ersatz-Preussen* and *Ersatz-Friedrich der Grosse* (to replace the before mentioned ships), whose principal dimensions were materially affected and restricted by the small size of the existing German dry docks, are being built now at the Imperial Dockyard at Wilhelmshaven.

The development of the unarmored ships was strongly influenced by closely adhering to and imitating the types of screw frigates and corvettes existing in the year 1871 in the German Navy, the type of the full-rigged single screw frigates and corvettes with broadside guns without any armor protection. The

vessels had full sailing capacity, and great stress was laid on the training of the crew in the rigging, but the fighting capacity of the vessels was neglected. Such vessels were constructed even as late as 1887 (*Charlotte*, *Arcona*, *Alexandrine*).

Cruisers to suit modern requirements were not commenced before 1885. Three of those vessels of the second class have been built up to now, the *Irene*, *Princess Wilhelm*, and the *Kaiserin Augusta;* the last of which is the first triple-screw ship which crossed the Atlantic. Up to 1895, only one moderately armed and protected cruiser of the third class (*Gefion*) was built, together with a number of smaller cruisers of the fourth class (*Bussard* type).

By this time the want of cruisers was felt so severely, that three second-class cruisers of more than 5,600 tons (*Ersatz-Freya*, *K* and *L*) and one first-class armored cruiser of 10,650 tons (*Ersats Leipzig*) were commenced. To these vessels were added this year two more cruisers of the second class (*M* and *N*).

A special feature in the German Navy has always been the "avisos," speedy vessels of small fighting capacity, designed only to serve as scouts for the fleet. But soon these vessels were required to fight, especially after the introduction of the torpedo; in consequence, the vital parts had to be protected. Out of the last German vessel of any size built abroad, by the Thames Ironworks, 1875–6, viz., the *Zieten*, the modern German "avisos" were developed. These were first of all the *Blitz* and *Pfeil* with underwater torpedo armament and of 16 knots speed, forerunners of the later built English boats, *Surprise* and *Alacrity*. The *Greif*, of 19 knots speed, succeeded in 1885, and was followed by the *Wacht* and *Jagd*, of 19½ knots speed, and fitted with a protective deck.

After these come two small "avisos" of the same speed, the *Meteor* and *Comet*, of 1,000 tons, and then the "aviso" *Hohenzollern*, a splendid vessel fitted out as an Imperial yacht, with 21.5 knots speed, of about 4,000 tons displacement. The last of the "avisos" is the *Hela*, of 2,000 tons displacement, now beginning her trials.

I will pass over the torpedo division boats and torpedo boats,

even though the development of these craft in Germany is very interesting.

This short review, perhaps, shows some of the difficulties which had to be dealt with to build up the navy. But now the strong influence of His Majesty, the Emperor, supported by the great efficiency of the German shipyards, and steel works, and all those other trades which help to finish a modern man-of-war, opened up the way for the new development.

In the years after 1870, as the material was needed for the naval vessels to be built in Germany, iron works had first to prepare to fiulfill the orders for material of the same quality as was required by the English rules, which were adhered to. Plates and angles were soon produced, just of the same good quality as in England; but it was difficult to forge heavy pieces, like stems, sternposts and rudder frames for bigger ships, and for several years these had to be ordered from England. To-day in this respect, too, German works are equal to any demand; the stem and sternpost, with rudder frame, of one of the armorclads of the *Brandenburg* type made by Krupp was much admired at the Exhibition in Chicago.

The production of armor plates for our armor clad ships and vessels shows a rather slow development. The armor plates were first ordered in England from Charles Cammell & Co. and John Brown & Co., both in Sheffield. In 1876 the Dillinger Works on the Saar made preparations to produce iron armor, and furnished, first, the 203 millimeter (8-inch) plates for a number of armored gunboats of the *Wespe* class, afterwards plates of 254 millimeters and 305 millimeters (10 inches and 12 inches) thick for two ships of the *Sachsen* type (the *Baden* and *Württemburg*), and in 1879–80, plates 305 millimeters (12 inches) thick for the reconstruction of the *König Wilhelm*.

In 1880 the Dillinger Works obtained the English "Wilson" patent for producing steel-faced armor plates (compound armor), and furnished those plates, first for the *Oldenburg*, and thereafter for all armor plated German ships, until, in 1890, steel faced plates were superseded by nickel armor plates, which are also produced by the Dillinger Works.

Since 1891 the works of Krupp, in Essen, also have made great preparations to manufacture armor plates. These two factories now work together, and not only can turn out all the armor plates needed in Germany, but execute foreign orders also. The latest face hardened armor plates of these two works are perhaps the best plates produced anywhere. Germany has become perfectly independent in this respect also.

England has been Germany's teacher in the construction of hulls, engines and boilers. Those ships which were bought from and built in England for the German Navy had to serve as standards from which to imitate the details. Our inspectors kept their eyes and ears open, and the many publications, as, for instance, Sir Edward Reed's and Sir William White's precious works, the Transactions of the Institution of Naval Architects, the instructive articles in the periodicals, "Engineer" and "Engineering," offered an abundance of information to those who intended to learn, like the Germans of that time. The engines of the screw frigate *Elizabeth* had to be ordered, in 1867, from England (Maudslay), because they could not be designed and built in Germany. The first larger screw engines for navy ships were constructed in 1871 and the following years at the works of Egells, in Berlin, for the corvettes *Ariadne* and *Luise*, and at the Vulcan Works in Stettin, 1874, for the armor clad *Hansa*. These engines were of English model in general design, and entirely so in all details.

But since that time German industry has made such progress in the building of large marine engines that it now comes up to the highest standard, and has grown to be wholly independent. Already, nearly 20 years ago, German manufacturers went their own way in working out the plans and the details of engines and boilers, taking advantage of all the new inventions in England and France.

To-day the construction of navy vessels in Germany is worked out from original ideas, in order to fulfill the military requirements for each type. The new German men-of-war now in course of construction will, in many respects, be worthy of interest, since all modern improvements in science and technical knowledge have

been taken advantage of to produce a most perfect tool for any war purpose.

I shall describe now, in a few words, some arrangements in which German men-of war, in my opinion, differ from the English built warships. I mention here, first of all, the divisions into water tight compartments.

The armorclads, armored cruisers and protected cruisers are divided into as many water tight compartments as it was deemed possible without interfering with the working of the vessel. Perhaps this is carried out already too far, and the service on board may be obstructed. The paper of Lord Charles Beresford, read before the meeting of the Institution in March of this year, mentions those considerations which prompted the constructor here to carry every athwartship bulkhead, above the water line, without any door in it. Any door may be left open, therefore one has to accept the probability that it will be left open, and consequently, it is better to have no door at all. Communication from one engine room to the other, from one stokehold to the other, must be established only over the protective deck, above water, or may be carried on below by telegraphs and speaking tubes.

Only in the athwartship bulkheads which are beneath the protective underwater deck of citadel ships, or in the foremost and aftermost parts of protected cruisers, doors are permitted. This circumstance speaks strongly against the construction of such vessels.

The above mentioned principle is strictly adhered to in all new German Navy vessels.

It is difficult to ventilate a ship divided in this way. Air from above must directly lead into, and out of, each compartment between two athwartship bulkheads, which has direct access from above. Only for the forward and aft compartments underneath the protective underwater decks, air ducts are carried through the athwartship bulkheads, and water tight shutters have to be provided for, which are perhaps insufficient, but have to be made use of in vessels of the citadel type.

Modern vessels suffer a great deal from the heat which radiates

from the steam piping belonging to the large number of auxiliary engines installed in all parts of the ship, and which supplies the ship with continuous steam heating. All attempts of engineers to cover these pipes with non-conducting materials, and to insulate them so as to prevent this radiating heat, have entirely failed, and every room through which a steam pipe is carried is heated very disagreeably. The best method of counteracting these effects of steam engines and steam pipes was found to be by omitting them, and by employing electricity, the conducting wire taking the place of the steam pipe. Only by driving the many fans made necessary for the water tight compartments by electricity is the division into so many compartments rendered at all possible.

All new German warships in course of construction have electricity as motive power, not only for those ventilating fans, but also for the turning gear of the 15 cm. gun turrets, for ammunition hoists, for boat hoisting and coaling winches and such like gear.

For the turning gear and ammunition lifts of the heavy guns, hydraulic power has been retained, and steam is still used for the steering gear where it was especially difficult to install the electric motor, as well as for the anchor windlasses, which are only comparatively seldom used. Only one vessel in the German Navy, the nearly finished *Aegir*, is experimentally fitted throughout with electric appliances even for steering gear and windlasses. The results of these experimental installations will decide if, in the future, electricity can be used more extensively for motive power on board ships, and if the heat sources can be further dispensed with.

His Majesty's cruiser *Kaiserin Augusta*, of 6,300 tons displacement, over 13,000 I.H.P., and with a speed, at load draught, of over 21½ knots, is the first German vessel with three screw propellers; she is also the first triple-screw steamer which ever crossed the Atlantic. [In 1893, in order to be present at the celebration of the four hundred years' jubilee of the Discovery of America.] It is hardly necessary to discuss at any length the considerations which caused the adoption of a system accepted

already some time before in Italy for the *Tripoli*, and decided on in France for the *Dupuy de Lôme*.

By dividing the excessive motive power of the modern warships into three parts, the smaller engines could be more easily constructed, and, as they do not stand so high, it is less difficult to place the vertical engines underneath the protective deck. In a combat additional security of working is provided, as compared with the twin-screw ships, and, lastly, saving of fuel should result in using only one of the smaller engines when cruising at reduced speed.

Although the engine room staff has to be augmented, greater engine space is required, and the three engines themselves are to a small extent heavier, these disadvantages were not considered important enough to outweigh the advantages of the triple screw for all battleships, and for the first and second-class cruisers in the German Navy. Triple screws are provided for the new battleships *Ersatz-Preussen* and *Ersatz-Friedrich der Grosse*, the armored cruiser *Ersatz-Leipzig* and the second-class cruisers *Ersatz-Freya*, *K*, *L*, *M* and *N*.

In all the new ships the armament, and its protection, in accordance with the latest experience, require so much of the weight which makes up the displacement, that somewhere else weight had to be saved, which would be available for armor and guns.

Nowhere could weight be reduced, since more was asked for everywhere. Though, to facilitate work, more auxiliary machinery is installed, the number of the crew is not diminished; these engines require even more attendants.

The weight of hull is, through rational construction and reduction of the scantlings, lessened as much as the strains will permit, in some cases even in excess of a sufficient margin of safety. Considerable reduction in the weight of the ships' hulls was effected by the restricted use of wood. The splinters of wood scattered by penetrating shells were always dreaded, the experiences drawn from the battle at Yalu have clearly shown how dangerous such combustible material as wood is for the construction of a ship and its fittings.

In the outfit and the construction of the new German ships,

wood is used only for a few minor parts. Wooden deck planks are no longer laid, steel deck plating is covered with linoleum, sometimes over a layer of cork. In the crew's quarters the sides of the ship are not ceiled, in the officers' rooms the ceiling is made of steel plates 1½ millimeters thick, and lined with cork. For cabin bulkheads the steel is covered with thin woolen cloth, and with cork lining underneath, where it is desirable to exclude sound or lower the temperature. Where heat is radiated from engine or funnel casings, cork lining is resorted to. All wood is removed from the ammunition rooms, save the racks for shells and powder charges, which are still made of wood. For all ladders and steps steel is used. The handrails on the conning bridges are no longer of wood, but of some other material, which will not burn or splinter, and which is more agreeable to the touch of the hand than steel or brass. Chart houses and captains' rooms on bridges are entirely made of steel, and fitted out with non-combustible materials. Since all such changes will be a little exaggerated, it seemed to be advisable to abandon wood for the interior fittings, and especially for the furniture, and to resort to fireproof material, which will not splinter. Many things were tried; furniture was made of steel and aluminium, lined with cork, and covered with linoleum or canvas, but it was not equal to wood furniture. Only the bedsteads are constructed of iron, steel or brass, which materials are also much in use ashore. The insignificant quantity of wood in the few pieces of furniture when ignited is not the dangerous source of smoke, but much more is the outfit of the staterooms, the mattresses, blankets, clothing, books, &c. Therefore for the present wood cannot be abandoned entirely.

Top and signal masts, flag poles, etc., will be made of steel, but there one can not save weight.

The fighting capacity of the ships is without doubt increased through these innovations, since the ship is less apt to burn; the effects of splinters are restricted, and considerable weight is saved, which is available for ordnance and armor.

But still greater reductions were needed, and though the power

of the engines had to be raised their weight had to be kept as low as possible.

In the engine department the condenser plant is now exceedingly complicated, also the boilers are at present very heavy in consequence of the high pressure used, boiler feed water, which was formerly not needed, has to be carried, and the weight of machinery has increased above that of the old engines with low pressure when the boilers were fed with sea water.

Granted the modern engines consume less coal, might it not be better to save weight with a less complicated engine and carry more coal? I only refer here to engines of war vessels where quite other conditions prevail than in the Mercantile Marine, where the vessels always go at full power, while the man-of-war very seldom utilizes the full power of her engines and boilers.

This is a chapter by itself worth the investigations of a specialist, who could thoroughly clear up this question, but it is outside the scope of this paper.

The engine weights could not be reduced, so one had to look for reduction to the boilers, which represent such a considerable weight. Here a reduction could be had by adopting the water tube boiler. This problem of the water tube boilers is one of the most important and difficult ones in modern marine engineering, and is very actively discussed in the English, French and German Navies. Subsequently to the French and English Navies, the German has also taken decided steps, accepting water tube boilers for many vessels.

Not less than four different kinds of water tube boilers are adopted for the new German ships now in course of construction, viz.:

Aegir,	armorclad	fourth class,	4,800 I.H.P.	.....Thornycroft	boilers.
Ersatz-Freya,	cruiser,	second class,	9,000 I.H.P.	....Niclausse	"
K,	"	"	"	...Belleville	"
L,	"	"	"	...Dürr	"

The two armorclads of the first class, as well as the armored cruiser, *Ersatz-Leipzig*, will be fitted with two-thirds cylindrical boilers and one-third water tube boilers of the system which will

be found best from the results of the trial trips soon to be commenced.

The English Navy seems to prefer Belleville boilers for bigger ships, the French Navy provides for these ships, together with the Belleville boiler, those of D'Allest and of Niclausse; the Dürr boilers are very similar to those last mentioned. The trial trips of this and the next two years will show more clearly the value of the different types of the boilers. All the so-called theoretical discussions and contentions are useless, only practical experience can decide this question, but years may lapse before it is settled.

In the future, the use of water tube boilers cannot be avoided in Navies. By fitting them for one-third of the engine power (13,000 I.H.P.), in first-class ironclads, about 140 tons of weight are saved; and the reduction of weight for second-class cruisers of 9,000 I.H.P., where water tube boilers are entirely used, amounts to about 280 tons. The combined working of water tube and cylindrical boilers was the subject of a paper at the meetings of the Institution last year, but no decided opinion was arrived at.

In the Dutch Navy, too, the combined system is adopted for the three new large cruisers, but in a different form to ours, as the Dutch intend to generate two-thirds of the engine power with water tube boilers, and one-third with cylindrical boilers. The leading idea in the German arrangement is that, as a rule, the vessel steams at reduced speed, and uses only one set of cylindrical boilers, keeping the other free for easy cleaning. The water tube boilers are provided in order to get up, in the shortest time, steam for the highest engine power, at all other times fires are drawn from those boilers.

The greater coal consumption seems to be a drawback to the use of water tube boilers; only actual trials of ships in service will decide the merits of each type of boiler. In the meantime we are in the dark. It is at any rate hazardous to proceed with the use of water tube boilers, so long as we have only the experience acquired in the French navy and nowhere else, but the increased fighting power demanded, which cannot be provided otherwise, forces us to such action.

What an engineer of note wrote a short time ago in the Daily

News is certainly correct, viz.: "In the next war the side which has the best boilers will win."

Some more characteristic features of German ships of war could be brought forward; for instance, the fact that the protective underwater deck is never cut through for ventilating or coaling purposes; then the peculiar construction of the cork-filled cofferdams; the singular shape of the stern and rudder; the very high bow and low stern; but it would take too much time to thoroughly deal with them.

The annexed Table contains the particulars of the German men-of-war of the latest type.

I trust, though this paper is necessarily very incomplete on account of the very short time available for its preparation, the Institution will perceive from it how hard we had to work here in Germany to call into existence a navy in the short space of a quarter of a century; how we had to study and to test in order to achieve the result that the vessels planned by German designers, and constructed out of German material in German dockyards shall be fully equal to the vessels of the old English and French navies.

I hope that this may be the case.

The discussion of this paper was opened by **Sir Edward Reed,** who said a few words of a complimentary nature.

Sir William White said that it was useless to attempt any useful criticism of a design if special features only were selected and dealt with. His own designs had been criticised, and in certain newspapers he was made to appear worse than incompetent. He accepted that as a necessary accompaniment of the office he held. He would say, however, that the designs of British ships were accepted by naval officers, and it was the function of the naval architect to incorporate into the design the features which the naval officer required. The paper, which bristled with controversial matter, put before the Institution what was considered the best in Germany. Sir William had received from a distin-

guished admiral who had fought and covered himself with glory during the late war in the Far East, a letter in which he had said that he was not sure what the lessons were that were to be learned from the battle of Yalu; that the thing which impressed him most was that it was the duty of an officer to do the best he could with the means placed at his disposal. Some of those who had not the advantages of a professional training, but who had especial facilities for making themselves heard, seemed, on the other hand, perfectly sure what should be done. In regard to water tube boilers being used in conjunction with cylindrical boilers in the same ship, he would say that the matter had been fully considered by the Admiralty, and they had thought it better to frankly accept the water tube boiler, and the Belleville type was selected because it was that of which they had been able to glean most experience. Sir William concluded by an expression of admiration for what had been seen of German shipbuilding, and said that the steel castings especially were admirable examples of work.

Mr. Thornycroft referred briefly to two points in the paper, namely, the distribution of power on shipboard by electricity, and the arrangement of boilers. In regard to the first, by electricity they would get rid of heat and loss through radiation from steam pipes, and the chance of fracture by shot and shell. He thought the system of mixing boilers was a mistake. He would prefer all tubulous boilers. A point he had noticed in regard to German war vessels was the absence of combustible material.

DETAILS AS T

Class of ship.	1st class battleship.
Name.	*Ersatz-Preussen.*
By whom designed....	A. Dietrich, constructor-in
When and where laid down.	Imp. dockyard, Wilhelmsh March, 1895.
Date of completion (presumed).	1898.....
Material of hull.....	Steel.....
Length between perpendiculars.	115.0 m.....
Breadth, extreme.....	20.4 m.....
Mean load draught....	7.85 m. .....
Displacement in tons of 1,000 kg.	11,130.....
Armament—	
(1) Ordnance	Four 24 cm. in two armor volving turrets.
	Twelve 15 cm. Q. F. in ar single casemates.
	Six 15 cm. Q. F. in armor volving turrets.
	Twelve 8.8 cm. Q. F. with s
	Twelve 3.7 cm. Q. F. ma guns.
	Eight 8 mm. Q. F. machine
(2) Torpedoes.....	One 45 cm.* stem tube.....
	Four 45 cm.† broadside tub
	One 45 cm.* stern tube.....
Armor—	
Belt.....	On ⅓ length from forward, ness 300, 250, 200, and 15 hardened steel.
Turrets...	24 cm. 250 mm. thick.....
	15 cm. 150 mm. thick.....
Casemates.....	15 cm. 150 mm. thick. .....
Conning towers.....	280 and 150 mm.....
Armored decks	On top of belt, 65 mm.; u water armored deck a mm.; splinter decks, 20 m
Makers of machinery.	Imp. dockyard, Wilhelmsha
Number of screws.....	3.....
Indicated horse-power	13,000.. .....
Engines.....	Vertical 3-cyl. triple expan
Boilers	For ⅔ power cyl. Scotch boi
	For ⅓ power water tube boi
Speed at load draught	18 knots.....
Coal capacity at load draught.	650 tons (of 1,000 kg.).....
Masts.....	Two military masts with fig tops, foremast with inside derways.
Number of crew.....	655.....

DETAILS AS TO GERMAN WARSHIPS IN COURSE OF CONSTRUCTION, 1896.

st class battleship.	1st class cruiser.	2d class cruiser.	2d class cruiser.	2d class cruiser.
Ersatz-Preussen.	*Ersatz-Leipzig.*	*Ersatz-Freya.*	K.	L.
rich, constructor-in-chief...	As before	As before	As before	As before.
ockyard, Wilhelmshaven, n, 1895.	Imp. dockyard, Kiel, Autumn, 1895.	Imp. dockyard, Danzig, October, 1895.	Vulcan works, Stettin.	Weser works, Bremen.
	1898–99	1897	1897	1897.
	Steel, wood sheated, Muntz metal bottom.	Steel		
	120.0 m	105.0 m		
	20.4 m	17.4 m		
	7.9 m	6.25 m		
	10,650	5,650		
cm. in two armored re-g turrets.	Four 24 cm. in two armored revolving turrets.	Two 21 cm. in two armored revolving turrets.		
15 cm. Q. F. in armored casemates.	Six 15 cm. Q. F. in armored single casemates.	Four 15 cm. Q. F. in armored single casemates.		
m. Q. F. in armored re-g turrets.	Six 15 cm. Q. F. in armored revolving turrets.	Four 15 cm. Q. F. in armored revolving turrets.		
8.8 cm. Q. F. with shields..	Ten 8.8 cm. Q. F. with shields..	Ten 8.8 cm. Q. F. with shields..		
3.7 cm. Q. F. machine	Ten 3.7 cm. Q. F. machine guns..	Ten 3.7 cm. Q. F. machine guns..		
mm. Q. F. machine guns..	Eight 8 mm. Q. F. machine guns.	Four 8 mm. Q. F. machine guns.	As before.	As before.
cm.* stem tube	One 45 cm.† stem tube	One 45 cm.† stem tube		
cm.† broadside tubes	Four 45 cm.† broadside tubes	Two 45 cm.† broadside tubes		
cm.* stern tube	One 45 cm.* stern tube			
ngth from forward, thick-00, 250, 200, and 150 mm. ned steel.	All round the water line, thickness 200 and 100 mm. hardened steel.			
250 mm. thick	24 cm. 200 mm. thick	21 cm. 100 mm. thick		
250 mm. thick	15 cm. 100 mm. thick	15 cm. 100 mm. thick		
250 mm. thick.	15 cm. 100 mm. thick	15 cm. 100 mm. thick		
150 mm	200 and 100 mm	200 and 100 mm		
of belt, 65 mm.; under-armored deck aft, 75 splinter decks, 20 mm.	On the citadel on top of belt, 50 mm.; before and abaft, 30 mm.; under water armored deck before and abaft, 50 mm.; splinter decks, 20 mm.	Horizontal above water part of protective deck, 40 mm.; inclined sides, 100 mm.		
ckyard, Wilhelmshaven....	Imp. dockyard, Kiel	Germania Works, Tegel, Berlin..	Vulcan works, Stettin.	Weser works, Bremen.
	3	3	3	3
	13,500	9,000	9,000	9,000
l 3-cyl. triple expansion....	Vertical 4-cyl. triple expansion..	Vertical three-cylinder triple expansion.	Vertical 4 cyl. triple expansion.	Vertical 4 cyl. triple expansion.
ower cyl. Scotch boilers....	For $\frac{2}{3}$ power cyl. Scotch boilers..	Niclausse boilers	Belleville boilers	Dürr boilers.
ower water tube boilers....	For $\frac{1}{3}$ power water tube boilers...			
s	18.5—19 knots	18.5 knots	18.5 knots	18.5 knots.
s (of 1,000 kg.)	1,000 tons (of 1,000 kg.)	500 tons (of 1,000 kg.)	500 tons (of 1,000 kg.).	500 tons (of 1,000 kg.).
ilitary masts with fighting foremast with inside lad-ays.	As before	As before	As before	As before.
	565	439	439	439

*Above water. †Submerged.

COMPARISON OF NEW BRITISH CRUISERS WITH THOSE BUILDING AT BARROW.

[Condensed from an article in London "Engineering," entitled "Our New Cruisers."]

The cruisers included in this year's programme resemble the types represented by the *Powerful*, *Niobe* and *Doris*, building by the Naval Construction and Armaments Co., Barrow-in-Furness, so that a study of their qualities is specially interesting. Of the *Powerful* class there is only one other building, the *Terrible*, at Messrs. Thomson's, Clydebank.

Of the class represented by the *Niobe* there are now building four, one each at Barrow, Fairfield, Clydebank and Pembroke; they were ordered last December, and four more are to be ordered in a few months. They are small *Powerfuls*, the differences being only in dimensions and speed, not in the general outline of form or equipment. Of the *Doris* class there are under construction nine—all launched, and some ready for trial. Three more are soon to be ordered under this year's programme, but they will have water tube boilers. To make the list complete, we may include in our review the new cruisers of the *Pelorus* class, of which two are nearing completion, while six have recently been ordered—two from Messrs. Palmer, two from the Earle's Shipbuilding Company, one from Elswick and one from Sheerness.

The general dimensions may best be tabulated:

	Powerful.	*Niobe.*	*Doris.*	*Pelorus* class.
Length between perpendiculars	500 ft.	435 ft.	350 ft.	300 ft.
Breadth, extreme	71 ft. 6 in.	69 ft.	54 ft.	36 ft. 6 in.
Draught, mean	27 ft.	25 ft. 3 in.	20 ft. 6 in.	13 ft. 6 in.
Displacement, tons	14,200	11,000	5,600	2,135
Power, I.H.P.	25,000	16,500	9,600	7,000
Speed, knots	22.25	20.5	19.5	20
Maximum coal capacity	2,975	2,000	1,065	500

As none of these vessels have been tried, the speeds and powers are given as designed, but these will be sufficient for our purpose. In view of the large number of modified *Powerfuls* ordered as a new class, it is suggestive to compare the elements in designs of the *Powerful* and *Niobe* classes. First the reduced draught of the latter gives them the advantage of being able to pass through the Suez canal; the reduction in draught alike in big cruisers and in the new *Canopus* battleships is commendable; like the *Majestic* class, neither the *Powerful* nor *Terrible* may navigate the Suez canal. The attainment in the *Niobes* of this desideratum has involved certain concessions in space and in weight, and a reduction in speed of nearly two knots.

Practically the whole difference in the length of the ships is accounted for by the less number of boilers. The boiler space in the *Powerful* class occupies 186 feet of the length of the ship, there being four athwartship divisions, while in the *Niobe* it is only 132 feet. The forward thwartship coal bunker is not included in either measurement. There is little difference in the engine room, 60 feet against 56 feet. In the *Powerful*, there is a middle line bulkhead through the boiler compartments; in the new cruisers there is no such division. As in the *Powerful*, there is only one athwartship coal bunker, right forward, with coal bunkers on either side above and below the protective deck; ammunition passages are made through the bunkers and under the protective deck. There are 30 boilers, eight in the three after and six in the forward compartment, all single-ended Belleville boilers. In the *Powerful* there are 48 boilers. Again, the width of the compartments owing to the "fining" of the ship lines is not tapered in the *Niobe*, but stepped down from 42 feet amidships to 34 feet forward. In the other parts of the ship, so far as space is concerned, the two vessels do not differ much.

As to weights, something like 720 tons is saved owing to the less power, and of this, 460 tons is due to the decrease in the number of boilers, as compared with the *Powerful*. There is little difference in the weight of armament.

In the weight of hull, a saving of 1,525 tons is due to the shorter length. Structurally, both ships are alike so far as the

difference in length admits. The double bottom is 3½ feet deep in the center line, 30 inches at the bilge, the shell plating is generally 22½ pounds, the teak sheathing averages 4 inches, and the bilge keels are 3 feet clear of the sheathing. There is one deck less, the orlop, in the *Niobe*, but she has, like the *Powerful*, the boat deck, which extends for 12 feet inwards from the bulworks, and not only admits of ready use of the boats free from the interruption of the guns on the upper deck, but also of free communication fore and aft, all without affecting materially the light on the upper deck.

The protection of the ship is on the same lines as in the *Powerful*. The deck, of three thicknesses of plate, is 4 inches on the slopes amidships, elsewhere 2½ inches. In both vessels there is great rise of arch—a characteristic of the design of all modern classes. In the *Niobe* this rise is 10 feet, starting from the shell of the ship, 6 feet 6 inches under the water line; in the *Powerful* it is 6 inches more in both cases; in the *Doris* class it starts 5 feet below the water line, rising 6 feet, against 4 feet in the *Latona;* and in the *Pelorus* class, 2 feet 6 inches, rising 3 feet 9 inches. A larger section is thus under the deck. As the deck extends below the water line for from 5 to 7 feet, the outer shell under the protective deck will not be so fully or so frequently exposed, even should the vessel roll heavily in action. Besides, the provision of bilge keels has reduced the probability of great angles of heel. At the junction of the protective deck and framing, there is a strong cellular structure above and below the armored deck. In the *Powerful* and *Niobe* the machinery is entirely under the protective deck, all hatches having cofferdams. The coal bunkers above and below the protective deck also protect the machinery spaces, and the protection of guns has been, in the new vessel as in the *Powerful*, carried out fully by the construction of casemates for all the 6-inch guns.

The installation of guns on the *Niobe* class includes only quick firers, electric ammunition hoists being fitted to the 6-inch guns—a new departure. In the *Powerful* and *Terrible* the hoists are worked by hand. The hoists are protected by 2-inch armor. Of the 6-inch guns, two are on the forecastle in the place of

one 9.2-inch breechloader in the *Powerful*, the height above water line being 32 feet, against 34 feet in the *Powerful*. There are also two aft on the upper deck, the height above water level being 22 feet, while the *Powerful's* 9.2-inch gun has a height on the poop of 32 feet. The forward guns train to 60 degrees abaft, and the after guns to 60 degrees forward, the beam. Four of the other twelve guns are on the upper deck, and eight on the main deck. There are thus six guns firing forward and six firing aft, those on the lower decks training from 92 degrees forward to 28 degrees abaft the beam. The four broadside guns on the main deck fire 60 degrees before and abaft the beam. As the *Powerful* has only twelve 6 inch guns, an effectual substitute has been provided for the 22-ton guns. The other guns of the *Niobe* are eight 12-pounders, 12 hundred-weight, on the broadside upper deck; two 12-pounders, 12 hundred-weight, on the forward upper deck, two 12-pounders, 12 hundred-weight, on the after main deck; two 12-pounder, 8 hundred-weight, boat and field guns on shelter deck aft; two 3-pounder guns at the forward end of the boat deck; 9 Maxims for boats. There are no military tops on the masts; the *Powerful* has two on each mast. There are two 18-inch submerged torpedo tubes on the broadside and one protected torpedo tube through the stern above the water line.

The general appearance of the ships will be the same, except as regards length and military tops. The new vessels will have the same high freeboard. Forward it is 32 feet instead of 34 feet, admidships 15.5 feet to the upper and 24 feet to the boat deck. This affords the advantage of a high gun platform and more comfort for the crew in a seaway, although it increases the target for enemies' fire. The new ships, also, will have four funnels, all circular; on the *Powerful*, the after funnel is circular and the three others, elliptical. There will be the same two bridges, one forward and the other aft.

We come now to the second class cruisers. The new *Minerva* class, to which the *Juno* and *Doris* belong, include in all six building by contract, and three completing in the dockyards. They have cylindrical boilers, but the three new vessels will

have water tube boilers. The vessels of this design have been evolved out of the *Latonas*, of which so many were constructed under the Naval Defence Act. The intermediate stage in the evolution is marked by the *Bonaventure* class.

The new vessels are 50 feet longer, being 350 feet, and of 4 feet greater draught, the displacement being 2,200 tons greater, or 5,600 tons. In all points they are immensely superior; perhaps the British taxpayer will accept as proof of this the relative cost—£270,000 against £180,000. The addition to length has enabled the same speed to be got practically for the same power as in the *Latona*, notwithstanding the increased displacement, which represents a very material addition in offensive and defensive qualities, there being five instead of two 6-inch quick-firing guns, a heavier protective deck, with quite double the radius of action, owing to larger coal, ammunition and provision storage capacity. For instance, the athwartship coal bunkers in the new ships occupy 24 feet of the length of the ship, apart from the broadside coal spaces, against 16 feet in the *Latona*. The length taken up by magazines is 58 feet forward and 42 aft, in all 100 feet, against 42 and 32 feet, respectively, in the *Latona*. There is greater height, and also more length for provisions and stores, so that the vessels can keep the sea and maintain a fight for a greater period—two most important qualities for vessels fighting at a distance from a base of action.

Again, the greater depth of the *Doris* class—12 feet 2 inches—not only increases the freeboard by 8 feet, but adds another deck, so that although both have three athwartship coal bunkers, including one between the boiler compartments, the *Doris* class carries coal also on the protective deck, where the *Latona* had stores and men's quarters. In the *Doris*, the men are on the deck above the protective arch, and have 7 feet 9 inches of clear headroom, instead of 6 feet 9 inches. There is not much difference in the space occupied by machinery—3 feet, the boiler rooms in the *Doris* being 80 and the engine room 48 feet, against 79 and 46 feet, respectively, in the *Latona*, but the power is about the same. The boilers have greater surface and weight, the increase for only 600 more I.H.P. being 130 tons.

The increase in stores reflects also on the utilization of the extra displacement. The maximum coal supply, for instance, is 1,100 against 552 tons. The weight of hull accounts for about 1,000 tons of the difference. Much of this is explained by the greater length, the scantlings being proportionately heavier, the shell plating being about 2½ pounds thicker, viz., 17½ pounds; the double bottom 3 feet deep instead of 2.5 feet; the teak sheathing 3½ inches thick, and the depth of the bilge keel 21 instead of 18 inches. For protection, a commendable and more liberal allowance has been made. The *Latona* has a deck 2 inches thick on the slopes, and 1 inch in the center; the thickness in the new vessels is 3 inches and 1½ inches respectively. As in the case of the bigger boats, the rise of arch is greater, the connection with the shell being 5 feet below the loadline, by brackets above and below, the frames being cut at the deck. In both *Latona* and *Doris* classes, the cylinders of the engines project above the deck level, and 5-inch armor has been provided around the tops of the cylinders, the batter being steeper, 21 degrees off the vertical, against 23 degrees in the *Latona*. In the *Latona*, this casemate was carried to the deck above, but in the new vessels a less height clears the cylinders, and over the top there are two thicknesses of plating instead of only armor doors and hatches as in the earlier ships. In the newer ships, notably in the *Pelorus* class, a still more effective provision is to be made. The protective deck is to be "bellied" out to cover the cylinders; it will thus be continuous.

We have indicated the increase in the number of 6-inch quick firing guns from two to five. On the forecastle there is one of those guns firing right forward, and 30 degrees abaft the beam, and on either side on the upper deck, there is a 6-inch gun training from right forward to 60 degrees abaft the beam; the two other guns are placed on either side aft, the four on the upper deck being built out on sponsons so as to fire in line with the keel. The broadside guns on the same deck are six 4.7-inch quick firers. On the main deck below, there are nine 12-pounders, four of which are on each side and two on the forecastle firing right forward, and two under the poop. In the new boats

there are military tops, each with two 3-pounder guns, the forward top being 10 feet higher than the mizzen. The *Latona* class had no military tops. The new boats have two submerged and one above water torpedo tubes, while the *Latona's* four were above water. This change has been accompanied by a liberal space for submerged tube rooms, while there is a roomy and well equipped torpedo workshop.

The eight third-class cruisers of the *Pelorus* type have water tube boilers, and differ in several respects from all other classes. To get high speed with light draught, the double bottom has been omitted, with a substantial saving in weight. On the draught given, it is possible to secure a large measure of protection, a good armament, and 7,000 indicated horse-power to give a speed of 20 knots. The hull weighs 1,110 tons, the shell plating being 12½ pounds, and the bilge keels, 18 inches deep. The protective deck is 2 inches thick at the sides and 1 inch at the center, rising from 2.5 feet below the water line at the sides to 1.25 feet above it at the center. Abreast of the machinery and boilers the deck will have a greater rise, thus dispensing with the armor casings used in previous ships around the projecting parts of the machinery. There is a double line of coal bunkers on each side of the boiler casings, above the protective deck, and a single line below.

The armament will consist of two 4-inch quick firing guns on the forecastle head, one on each side, firing from right ahead to 50 degrees abaft the beam; two 4-inch guns on the poop with similar range; four 4-inch guns in broadside, firing 60 degrees forward and aft the beam; two 3-pounder guns under the forecastle, two under the poop, two on the broadside aft, and two on the broadside forward; these smaller guns training to the same arcs as the larger guns. There are two 14-inch deck torpedo tubes firing on the broadside 60 degrees forward or abaft the beam. The boiler space is 80 feet long by 24 feet wide, and the engine room, 38 feet long and the full width of the ship. The total estimated weight of machinery is 360 tons. The engines are of the triple-expansion type, the cylinders being 20½, 33 and 54 inches in diameter, the stroke being 27 inches. The power

under natural draft is to be 5,000, and under forced draft, 7,000 I.H.P., so that the power expected per ton of machinery is 19.4 I.H.P. under forced draft. This compares with 17 I.H.P. got with similar sized vessels having locomotive boilers, and with 13 I.H.P. in small cruisers having ordinary cylindrical boilers.

In the *Doris* type of engine, the H.P. cylinder has a piston valve, and the others double ported slide valves, all actuated by the ordinary link motion. The piston valves are balanced, and relief rings are fitted to the I.P. and L.P. valves. The piston rods and valve spindle glands are fitted with metallic packing. All forgings are of mild steel. The pistons are conical, the angle of the low pressure being about 23 degrees and the thickness, 42 inches at the boss and $1\frac{1}{8}$ inches at the rim. The piston rods are 7 inches in diameter; the connecting rods are 6.5 feet long and 6.5 inches in diameter at the smallest part. The crank pins are 14 inches in diameter and 16 inches long. The crank shaft is made in three interchangeable parts of forged steel, and is $13\frac{1}{4}$ inches in diameter, while the bearings are 16 inches long. The thrust block is of the horseshoe type, the total surface in each block being 1,252 square inches. The stern shaft is 15 inches in diameter. All shafting is hollow. These dimensions apply to the 9,600 I.H.P. engines of the *Juno* and *Doris*, and differ very little from those of the 9,000 I.H.P. engines for preceding cruisers. The air pumps are driven from the H.P. crosshead, and are arranged to deliver through filter tanks into the main feed tanks. The condensers, of naval brass, are placed at the after end of the engines. The cooling surface in the case of the *Juno* and *Doris* is 10,600 square feet, and separate circulating pumps are provided. Auxiliary condensers are fitted.

Practice in the cylinder details does not show any material difference between one set of engines and another, nor between the machinery of warships and high speed merchant steamers. The element of weight affects the framing and the construction of the condenser. In the cruisers of 9,000 and 9,600 I.H.P., cast steel bed plates of channel section were adopted, with cast iron back columns and wrought steel front columns, but in the *Jason* class, with 3,500 I.H.P., where weight was of still greater im-

portance, cast steel bed plates of H-section were used, with wrought steel back and front columns. In fast channel steamers, the cast iron bed plate is of ordinary box form with flat bottom, cast iron front columns and wrought steel back columns. The weights of the framing of these three types are given in the following table:

Name.	Weight of bed plates complete.			Weight of columns and guides.			Total weight of bed plates and columns.		
	Tons.	*Cwt.*	*Qrs.*	*Tons.*	*Cwt.*	*Qrs.*	*Tons.*	*Cwt.*	*Qrs.*
Jason class	5	1	3	4	6	1	9	8	0
Latona class	9	17	1	16	16	0	26	13	1
Fast twin screw steamer, *Duke of Lancaster*	16	1	0	16	15	0	32	16	0

In the case of the *Juno* and *Doris*, with framing much of the same type and weight as in the *Latona* and *Majestic* classes, the weight works out to .081 cwt. per I.H.P. against .12 cwt. in the *Duke of Lancaster*, and .35 cwt. for a Clan liner intended principally for cargo carrying; but in torpedo boat destroyers, where steel is used for columns and bronze for bed plates, the weight is reduced to .02 cwt. per I.H.P. The new cruisers of the *Powerful* class, however, differ entirely from the others. The standards are cast steel of box section, and there are two in front and two behind for each of the four cylinders, so that the surface is the same on the ahead and astern guides. There is, however, a material addition to the weight of the framing, the proportion being .133 cwt. of framing per I.H.P. against the .081 cwt. in the *Doris*. The bed plate and framing combined of the *Niobe* is about .128 cwt. per I.H.P.; these are practically of the same type as on the *Juno* and *Doris*, but the number and arrangement of the cylinders are the same as on the *Powerful*—four cylinder, triple expansion. The H.P. and I.P. cylinders have piston valves, and the two L.P. cylinders, the ordinary double ported slide valves, actuated by double eccentric link motion. The H.P. and I.P. cranks are placed directly opposite each other; the two low pressure cranks are also opposite, but at right angles to the high and intermediate pressure.

The difference in the size of the cylinders between naval and merchant practice is evident, if the ratios of the volume of the high to low pressure cylinders are considered. In the *Duke of Lancaster*—a fast twin-screw Channel steamer—it is 1 : 5.22; in the Pacific mail steamers named, 1 : 6.56; and in the Clan liners, which may be said to represent the cargo carrier, 1 : 7.5; but this latter is affected largely by the 200 pounds against 160 pounds pressure. In the Admiralty vessels, the ratio is lower. In the *Latona*, *Flora* and *Juno* classes, the ratios are practically alike; for the latter it is 1 : 5.04. Some of the Naval Defence cruisers had a ratio of 1 : 4.88, and the *Majestic* battleships approximate this, 1 : 4.85. Of course, it will be readily understood that in the case of Pacific liners, which indicate merchant liner practice, the vessel is always running with full power, and therefore in design, economy and equal loads on the pistons are sought at this power; in a cruiser, the usual or cruising speed is with about three-fourths power. It is further interesting to note that with the great increase in the initial steam pressure in the *Powerful* and the *Niobe*, the ratios are greatly affected. In the former, with 260 pounds pressure in the boilers, and reduced to 210 pounds at the engines, the ratio is 1 : 5.71; in the latter, with 300 pounds pressure in the boilers, reduced to 250 pounds at the engines, the ratio is 1 : 7.1; while in the *Pelorus*, with similarly high pressure, the Admiralty specifications indicate a ratio of 1 : 6.94. When we come to the torpedo-boat destroyers, although the pressure is 200 pounds in the *Sturgeon*, and 250 pounds in the boilers reduced to 220 pounds at the engines for the *Avon* class, the ratios are 1 : 5.45 and 1 : 5.475, respectively. Here the result is probably affected by the desire to get the highest power for a minimum weight without regard to practice; the piston speed is abnormally high.

In the vessels included in the table, all types of boilers are represented—the double-ended cylindrical boiler in the *Latona*, the single-ended boiler in the *Flora*, *Juno*, *Majestic* and others; the locomotive boiler in the *Jason* class, the small tube water tube boiler in the destroyers *Sturgeon* and *Avon*, and the proposed *Pelorus*, and the Belleville boiler in the *Powerful* and *Niobe*, while Howden's system in the Clan liners can be compared with the

closed stokehold system in the others. It will be noticed that a more liberal allowance has been made in the *Juno* and *Doris* cruisers than in the earlier cruisers—the *Latonas*, for instance—especially in tube surface, the heating area being 1.95 square feet per unit of power against 1.7, while the I.H.P. per ton of boiler is only 17, against 19 to 21 in the *Latonas* and *Edgars* of the Naval Defence fleet. The power per ton of machinery is therefore less, 10.7 against 13 in the *Latonas*, and the power per unit of weight of boilers is 17 against 21.8 horse power per ton. In the *Jasons*, with locomotive boilers, the power got per ton of machinery was 17, and per ton of boiler, 29. In the Clan liners, with Howden's system of forced draft, and where no consideration was given to economy in weight, the power per ton of machinery is 6.86, and per ton of boiler 13, which latter is most satisfactory.

Attention will at once be attracted to the results anticipated in connection with the *Powerful* and *Niobe*, in view of the installation of Belleville boilers. We have already referred to the more liberal allowance in engine framing, and may also add that the bearing surfaces are in excess of former practice. In the *Powerful*, for instance, the bearings of the crankshaft are 23 inches long and 20 inches in diameter; the crosshead pin bearings are each 13 inches in diameter by 13 inches long. In the *Niobe*, which is a smaller engine, each crankshaft bearing is 21 inches long and 17½ inches in diameter, and the crosshead pin bearings are each 11 inches in diameter by 10 inches long. As regards the boilers, they are much more ample than in the case of vessels with cylindrical boilers; that is reflected in the small power anticipated per square foot of grate—under 11 horse power—whereas even with natural draft 13 to 15 is got with other boilers; probably a greater margin is allowed. Again, the heating surface per unit of power is higher—2¾ against 1¾ to 2 with cylindrical boilers. The power should, therefore, be easily attained. These facts should be borne in mind in comparing weights, for they explain in some measure the fact that the power per ton of weight in the boiler room is 22 to 23, as compared with 17 to 19 with the ordinary successful multitubular steam generator.

In the torpedo-boat destroyers, there is the same ample provision in heating surface, although here the quick generation of steam gives a higher result per square foot of grate area—25 I.H.P.

The power per ton of machinery is 41, and per ton of boiler, 74. Three 27-knot boats were built, and all went through their official speed trials successfully; they manœuvred well, turning a circle within a diameter of 800 feet; and they steamed 45 nautical miles at a speed of 13 knots for a consumption of 1 ton of coal. In the 30-knot destroyers, of which four are now being constructed, some changes in the design of the machinery have been made. There will be two low pressure cylinders, so that the size is minimized, being 34 inches. There will be four cranks, equally balanced, and, as before, steel columns will be used with bronze bedplates. Thornycroft's boilers are to be fitted, the power to be developed being 6,000 I.H.P.

Some indication may be given of the rapidity attained in the construction of the machinery of the *Niobe*. After an order has been placed for naval machinery, detailed drawings have to be approved by the Admiralty before much can be done, and this can only be facilitated when to the experience of the management there is added a ready appreciation of all requirements. The *Niobe* was ordered on November 1, 1895, all the important drawings were approved by January 5, 1896, and work at once entered upon. All the principal patterns were made by February 14, the last of the eight cylinders was cast on May 1, some of them by this time being at the machines, while the last cylinder was bored on June 16.

PARTICULARS OF MACHINERY OF REPRESENTATIVE MODERN STEAMERS, NAVAL AND ME
BARRO

Name or class.	Cylinders, stroke.	Working pressure.	Type of engines.	Indicated horse-power.		Air pressure.	Number and of boiler
				Natural draft.	Forced draft.		
		Lbs.				*Ins.*	
Australia †	36 in., 51 in., 78 in. by 42 in.	137	Horizontal T. S. triple.	5,810	8,876	1.7	
Edgar †	40 in., 59 in., 88 in. by 51 in.	155	Vertical triple	10 172	12 550	0 7	8 cylindrica
Pelorus (proposed) †	20½ in., 33 in., 54 in. by 27 in.	250 to 300	Three-crank triple	*5,000	*7,000	...	8 Thornycr
Majestic	40 in., 59 in., 88 in. by 51 in.	155	do.	10,418	12 497	0 77	8 cylindrica
Powerful (two low-pressure cylinders).	45 in., 70 in., two 76 in. by 48 in.	260	Four-crank triple	*18,000	*25,000	...	48 Bellevill
Niobe (two low-pressure cylinders).	34 in., 55½ in., two 64 in. by 48 in.	300	do.	*12,500	*16,500	...	30 Bellevill
Latona	33½ in., 49 in., 74 in. by 39 in.	155	Three-crank triple	7,261	9,455	1.3	5 cylindrica
Flora	33 in., 49 in., 74 in. by 39 in.	155	do.	7,187	9,008	1.3	8 cylindrica
Juno	33 in., 49 in., 74 in. by 39 in.	155	do.	*8,000	*9,600	1	8 cylindrica
Jason	22 in., 34 in., 51 in. by 21 in.	155	do.	2.676	3.552	2.1	4 locomotiv
Sturgeon class	18 in., 27 in., 42 in. by 18 in.	200	do.	.....	4,492	2.5	4 Blechynd
Avon and *Bittern* (two low-pressure cylinders).	20½ in., 31 in., two 34 in. by 18 in.	250	Four-crank triple	.....	*6,000	2.5	4 Thornycr
Empress of India, *Empress of China*, *Empress of Japan*	32 in., 51 in., 82 in. by 54 in.	160	Three-crank triple	7.979 Howden's	assisted. 10,000 forced dft.	0.75	4 double e cylindri
Clan Liner	23 in., 38 in., 63 in. by 42 in.	200	do.	.....	2,300	1	2 cylindrica
Fast twin-screw steamer *Channel*.	24 in., 36 in., 55 in. by 33 in.	160	do.	3.395	5.473	1½	2 double-e cylindrica
Fast paddle	Two 50 in., two 88 in. by 72 in.	87	Four cylinder, two-crank compound.	.....	6,200	...	4 double-e cylindrica

† The first three vessels in the table were not engined at Barrow; we

MERCANTILE, CONSTRUCTED BY THE NAVAL CONSTRUCTION AND ARMAMENTS COMPANY, LIMI
ROW-IN-FURNESS.

and type ilers.	Total		Weights.		I.H.P. per ton of machinery.		I.H.P. per ton in boiler rooms.		I.H.P. per square foot of grate surface.		Heating surface per I H.P.		Remarks.
	Heating surface.	Grate surface.	Total weight of machinery.	Weight in boiler rooms.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
	Sq. ft.	*Sq. ft.*	*Tons.*	*Tons.*									
.....	15,191	513	780	413.2	7.44	11.3	14.06	21.48	11.32	17.30	2.61	1.71	From Mr. Durs paper.
rical	24,879	849	1,135	639 8	8.96	10.9	15.99	19.61	11.98	14 78	2.44	1.98	Do.
ycroft	17,720	352	360	.....	13 88	19.44	.....	.....	14.20	19.88	3 54	2.53	*Estimated.
rical	25,570	821	1,300	736	8.01	9.61	14.15	16.99	12.68	15.22	2 45	2.04	
ville	69,453	2,192	2,250	1,184	8.0	11.11	15.20	21.1	8.21	11.40	3.85	2.77	*Estimated.
ville	45.915	1,449	1.525	720	8 19	10.81	17.36	22 91	8.62	11.38	3.67	2.78	*Estimated.
rical	15,881	581	728	433 6	9.97	13	16.74	21.80	12.49	16 27	2.18	1.67	
rical	15.789	581	780	458	9.21	11.53	15.69	19.66	12.37	15 50	2.19	1.75	
rical	18,750	599	900	564	8.88	10 7	14.18	17.02	13.35	16.02	2.34	1.95	*Estimated.
tive	6,388	182	208	122.5	12 67	17.1	21.84	29	14.70	19.51	2.38	1.79	
nden	9.652	156	109	60.5	.....	41.21	.....	74 24	.....	28.79	.....	2.14	
ycroft	13,400	236	145	81	.....	41.31	.....	74.07	.....	25.42	.....	2.23	*Estimated.
e ended drical.	20,193	701	1.439	715	5.54	6.95	11.15	13.98	11.26	14.25	2 53	2.01	
rical	4,140	95	335	175	.....	6.86	.....	13.14	.....	24.21	.....	1.8	
e-ended rical.	9,419	276	525	313	6.46	10.35	10.84	17.48	12 30	19.83	2 77	1.72	
e-ended rical.	12,249	525	688	367	.....	9.05	.....	16 89	.....	11.80	.....	1.97	

we have added them to the table for the sake of comparison with modern work.

TICULARS OF MACHINERY OF REPRESENTATIVE MODERN STEAMERS, NAVAL AND MERCANT
BARROW-IN-FU

Name or class.	Cylinders, stroke.	Working pressure.	Type of engines.	Indicated horse-power.		Air pressure.	Number and type of boilers.
				Natural draft.	Forced draft.		
		Lbs.				*Ins.*	
ralia †.....	36 in., 51 in., 78 in. by 42 in.	137	Horizontal T. S. triple.	5,810	8,876	1.7	.....
r †.....	40 in., 59 in., 88 in. by 51 in.	155	Vertical triple.....	10 172	12.550	0 7	8 cylindrical .....
us (proposed) †.....	20½ in., 33 in., 54 in. by 27 in.	250 to 300	Three-crank triple...	*5,000	*7,000	...	8 Thornycroft .....
stic.....	40 in., 59 in., 88 in. by 51 in.	155	.....do.....	10,418	12.497	0 77	8 cylindrical .....
rful (two low-pres- e cylinders).	45 in., 70 in., two 76 in. by 48 in.	260	Four-crank triple....	*18,000	*25,000	...	48 Belleville .....
(two low-pressure inders).	34 in., 55½ in., two 64 in. by 48 in.	300	.....do.....	*12,500	*16,500	...	30 Belleville .....
na.....	33½ in., 49 in., 74 in. by 39 in.	155	Three-crank triple ..	7,261	9,455	1.3	5 cylindrical .....
.....	33 in., 49 in., 74 in. by 39 in.	155	..... do.....	7,187	9,008	1.3	8 cylindrical .....
.....	33 in., 49 in., 74 in. by 39 in.	155	.....do.....	*8,000	*9,600	1	8 cylindrical .....
....	22 in., 34 in., 51 in. by 21 in.	155	.....do.....	2.676	3.552	2.1	4 locomotive .....
eon class.....	18 in., 27 in., 42 in. by 18 in.	200	.....do.....	.....	4,492	2.5	4 Blechynden .....
and *Bittern* (two -pressure cylinders).	20½ in., 31 in., two 34 in. by 18 in.	250	Four-crank triple ...	.....	*6,000	2.5	4 Thornycroft .....
ess of India..... } *ess of China*..... } *ess of Japan*..... }	32 in., 51 in., 82 in. by 54 in.	160	Three-crank triple...	7.979 Howden's	assisted. 10,000 forced dft.	0.75	4 double ended cylindrical.
Liner.....	23 in., 38 in., 63 in. by 42 in.	200	.....do.....	.....	2,300	1	2 cylindrical .....
twin-screw steamer *nnel.*	24 in., 36 in., 55 in. by 33 in.	160	.....do.....	3.395	5.473	1½	2 double-ended cylindrical.
addle.....	Two 50 in., two 88 in. by 72 in.	87	Four cylinder, two-crank compound.	.....	6,200	...	4 double-ended cylindrical.

† The first three vessels in the table were not engined at Barrow; we have add

NTILE, CONSTRUCTED BY THE NAVAL CONSTRUCTION AND ARMAMENTS COMPANY, LIMITED, FURNESS.

Total		Weights.		I.H.P. per ton of machinery.		I.H.P. per ton in boiler rooms.		I.H.P. per square foot of grate surface.		Heating surface per I H.P.		Remarks.
Heating surface.	Grate surface.	Total weight of machinery.	Weight in boiler rooms.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	Natural draft.	Forced draft.	
Sq. ft.	*Sq. ft.*	*Tons.*	*Tons.*									
15,191	513	780	413.2	7.44	11.3	14.06	21.48	11.32	17.30	2.61	1.71	From Mr. Durston's paper.
24,879	849	1,135	639 8	8.96	10.9	15.99	19.61	11.98	14 78	2.44	1.98	Do.
17,720	352	360	.....	13 88	19.44	.....	.....	14.20	19.88	3 54	2.53	*Estimated.
25,570	821	1,300	736	8.01	9.61	14.15	16.99	12.68	15.22	2 45	2.04	
69,453	2,192	2,250	1,184	8.0	11.11	15.20	21.1	8.21	11.40	3.85	2.77	*Estimated.
45.915	1,449	1.525	720	8 19	10.81	17.36	22 91	8.62	11.38	3.67	2.78	*Estimated.
15,881	581	728	433 6	9.97	13	16.74	21.80	12.49	16 27	2.18	1.67	
15.789	581	780	458	9.21	11.53	15.69	19.66	12.37	15 50	2.19	1.75	
18,750	599	900	564	8.88	10 7	14.18	17.02	13.35	16.02	2.34	1.95	*Estimated.
6,388	182	208	122.5	12 67	17.1	21.84	29	14.70	19.51	2.38	1.79	
9.652	156	109	60.5	.....	41 21	.....	74 24	.....	28.79	.....	2.14	
13,400	236	145	81	.....	41.31	.....	74.07	.....	25.42	.....	2.23	*Estimated.
} 20,193	701	1.439	715	5.54	6.95	11.15	13.98	11.26	14.25	2 53	2.01	
4,140	95	335	175	.....	6.86	.....	13.14	.....	24.21	.....	1.8	
9.419	276	525	313	6.46	10.35	10.84	17.48	12 30	19.83	2 77	1.72	
12,249	525	688	367	.....	9.05	.....	16 89	.....	11.80	.....	1.97	

added them to the table for the sake of comparison with modern work.

USE OF ELECTRICITY ON BOARD SHIPS.

By Herr F. Eickenradt, Engineer Inspector.

[Read at the Summer Meeting of the Thirty-seventh Session of the Institution of Naval Architects, June 13, 1896.]

In endeavoring to comply with the flattering request of speaking before this assembly, I have chosen for this purpose a subject which at the present time should engage the attention of shipbuilders in general, viz:—

USE OF ELECTRICITY ON BOARD SHIPS.

First of all, I beg leave to request the distinguished company here assembled not to criticise my statements with the eye of the technical electrician, as I do not pretend to pose as a specialist in this subject. I rather shall endeavor to treat the question merely from the point of view of the shipbuilder.

Excepting in isolated cases of minor importance, electricity has only been recently brought into more extensive use for working auxiliary machinery on board of ships. Not only has the technical electrician endeavored in the last few years to interest the shipbuilding industry in the application of electricity, which took such enormous strides in its development, and to draw the equipment of ships into the province of their commercial supplies; but also the shipbuilder—whose work may be described as a rallying point of every new technical invention developed to its utmost extent and completeness, and who is thereby obliged to follow every further step onward with ever-watchful eye—could not afford to neglect the obligation to make a practical test of the value of the electric motor on board ships.

The first question, from the point of view of the shipbuilder, was to ascertain whether electricity, as such, had special advantages to offer over steam power, hitherto generally employed.

This question may be answered with a decided "yes" in many cases. The large number of auxiliary engines which are in use on board modern steamers, and still more so on men-of-war, not only as accessories to the complicated main engines, but also for all other possible purposes, necessitated the laying of steam pipes into almost every nook and corner of the ship, both for the purpose of bringing steam power to the spot, and for carrying away the waste steam after use, a fact which does not exactly contribute to the comfort of the crew. This network of pipes produces, notwithstanding the most careful covering with non-conductors, not only troublesome and unnecessary heating of spaces where it is not required, but leads to still greater inconveniences in consequence of the damages to which such steam pipes are unavoidably subjected. The leaking of a single flange may make staying, even in large rooms, perfectly impossible. All these evils are avoided if the transmission of power to the different points for use is effected by a wire, which, when properly adjusted as to dimensions and well insulated, has absolutely no effect upon its surroundings.

The second question is, whether the electric motor is superior to the steam motor. As to this, it must be admitted that a steam engine in every part of the ship is disagreeable; it emits heat, and is exposed to many accidents, which may produce detrimental, and, in some cases, even disastrous, effects to its vicinity. Such accidents do not arise to the same degree with the electric motor, besides which it has the advantage of being very simple to manipulate, as long as it is at all efficient for use, and, what is especially of importance for the circumstances on board ship, it is much more clean to handle than a steam engine.

I make this reservation with the electrical motor, "as long as it is efficient for use." This point appears of importance in regard to its usefulness on board. The electric motor has, however, hitherto remained quite unknown to the engine room *personnel*. They are not sufficiently familiar with its arrangement, especially with the often very complicated supplementary contrivances, and they do not know what to do when a breakdown occurs. On the other hand, it must be admitted that the

technical electrician has already recognized this fact to a certain extent, and has provided for it, partly by simplifying every apparatus which will have to be entrusted to unskilled hands as much as possible, the reliability of the working of which has to be safeguarded under any circumstances, and partly by excluding those parts which do not require special attention from any possibility of being touched by incompetent hands. Supposing that a motor has been constructed, in this respect, with the most complete perfection, the only attention it would require would be that, at certain intervals, it is necessary to inspect the bedplates, and to ascertain the condition of the insulation in the wires. With such simple attention, it becomes possible to supervise several motors, which are worked from a common center, by a very limited number of hands, which undeniably is a great advantage.

I shall now proceed to consider successively the following subjects, viz.: Installations for lighting, ventilation and heating, ships' winches, ammunition supplies, appliances for moving guns, and steering apparatus.

LIGHTING.

When electric lighting was first introduced, there were, indeed, many opponents, but to-day its abolition is beyond any discussion. Its reliability of working is fully safeguarded with the dynamos in use at the present time, and any danger of fire is as good as excluded, when the installation is properly and scientifically made; therefore, the advantages of electric lighting are now so generally acknowledged that even on small cargo steamers, where only a limited number of lamps are required, a small dynamo engine is installed for lighting purposes. Electric lighting installations are indeed reckoned amongst the sanitary fittings of ships, and while mentioning this, we are involuntarily driven to the question whether in this respect further improvements might not be obtained by means of electricity. In answer to this question we are led to consider ventilation and heating apparatus.

VENTILATION.

Good ventilation on board, both for living rooms and cargo spaces, may now be considered as a generally admitted necessity.

But every shipbuilder is aware of the difficulties which the solution of this question presents in regard to natural ventilation, and artificial ventilation has therefore taken its place everywhere on board already.

An arrangement of tubes emanating from a central point and leading into every part of the ship would appear to be the most advantageous. However, the carrying out of such a system would be connected with enormous difficulties, considering the circumstances on board ship, and having regard to the conditions which would have to be fulfilled in order to make it efficient; and especially taking into consideration the necessity of preserving the water tightness of the bulkheads, which would absolutely forbid the passage of air-tubes through them. The shipbuilder is therefore obliged to divide the entire system of ventilation into several parts, each independent of the other, and must make allowance for the division of the ship into water tight compartments. For the working of these separate ventilators, which frequently have to be fitted up in out-of-the-way corners, which are difficult of access, a steam engine has to be again supplied, to which the evils previously enumerated are especially applicable, and which necessitates again a special attendance. For the working of such ventilators, therefore, the electro-motor is excellently adapted, and its driving may be effected from any easily accessible place with the same facility as if it were situated in the immediate vicinity of the ventilator. The kind of motor here in question is of very simple construction, does not require any complicated auxiliary arrangements, and will keep on running without any attendance at all.

If there are not many ventilators of large dimensions to drive, the installation of a separate current circuit may be avoided, and the ventilators may be connected with the circuit for the lighting, for which purpose the latter will only experience an immaterial addition to its weight. Should there, however, be several ventilators with fans of 800 to 1,200 millimeters diameter, and demanding a current of 2,000 to 4,000 Watts, it is preferable to establish a separate circuit for them.

With regard to the advantages of the electro-motors for this

purpose, it is anticipated that they will be generally adopted for the driving of ventilators, and this may occasion, again, an improvement of the systems of ventilation, as they may be extended to spaces which hitherto have been excluded.

Also, the ventilators for the stokeholds of boilers under forced draft, having a consumption of energy of from 15,000 to 20,000 Watts each, and the engine room ventilators with a consumption of 6,000 to 10,000 Watts each, are advantageously driven by electro-motors, because every unnecessary addition of heat to these rooms, which are already very hot in themselves, should be avoided, and because the installation of the ventilators in the heating rooms is often such that the attendance upon a steam motor is thereby made very difficult. In places like the above, where the electro-motors are exposed to the particularly severe effects of coal dust and heat, it is further advantageous, for the maintenance of the good condition of the motor, to construct it inside the suction tube of the ventilator, which can easily be done in centrifugal ventilators, with separate air suction tubes; by such an arrangement the electro-motor will be well protected and kept cool.

ELECTRIC HEATING.

Very little experience is available up to date in respect to electric heating, and, as far as I know, experiments in that direction have only been commenced at a very recent period. Installations for this purpose would offer a great advantage, by enabling us to dispense with the very extensive pipe system required for the steam heating process, with its innumerable flanges, taps, valves and condensing pipes, all of which details occasion frequent inconvenience, in consequence of leakages and failures in the action of the condensing apparatus. Many perforations through bulkheads are also dangerous inconveniences. All these evils would be avoided in electrical heating, the conducting wires for which could be suitably joined to those for the lighting apparatus, with the object of minimizing weight and restricting the number of conduits generally, as much as possible. The disadvantage of such an installation consists, however, in the fact that a comparatively large main engine for the generating of current would

have to be erected, and that this force would only be fully employed while the limited period for heating lasts. If you take it for granted that a steam heating apparatus, with heat-giving copper tubes and a total heating surface of 75 square meters, would produce hourly a heat of 60,000 calories, an electric heating apparatus of the like power would require a main engine of about 75,000 Watts strength, consequently a steam engine of about 100 H.P. The erection of such an engine exclusively for this purpose would, however, only very rarely be suitable for ships. But in case an electric motor is contemplated, say, for boat hoisting apparatus, etc., which would not be often in use, and then only for a short period, the necessary engine for this purpose might in the interval be used with great advantage for heating.

Electric heating all over a ship can, therefore, at present not come into consideration, but it might be advantageous for many spaces where electric lighting has already been resorted to, and where a connection with a steam heating system presents other difficulties.

I should like to mention here that the preceding remarks have been based upon a supposed transmission of 800 calories per hour and per square meter of copper tube in the steam heating surface. Absolute reliance, however, cannot yet be placed on these figures, and likewise the transmission co-efficients have not yet been exactly ascertained, which have to be taken into account for circumstances on board ship. The introduction of electric heating on board, which requires an exact previous calculation of the heating surface and of the dynamo engine, still necessitates therefore the investigation of the above mentioned transmission co-efficients on existing steam heating installations.

SHIPS' WINCHES.

The manufacture of electric ships' winches forms already a special department with the electrical engineering firms. They are now so thoroughly understood in all their branches that their general adoption for ships may be confidently anticipated in the near future. The excellent results which many German firms have also shown in this branch have further induced them to go

a step forward, from the comparatively simple winches for loads up to 2,000 kilos and 3,000 kilos, to the heavy boat lowering winches, with a lifting capacity of 10 tons to 16 tons. Such installations, which require a development of force equal to 90 to 100 H.P., can, however, only be advantageously employed when the electro-motor has been adopted for all the auxiliary machinery in a ship. In an installation of this kind, it is not requisite that the power of the main engine equals the sum total of the capacity of all the auxiliary engines; the calculations must rather be based upon the total of all the engines which may be in use at the same time. During the period of employment of a boat winch of 50 H.P., which is driven by a central engine, it will always be possible to disconnect a corresponding number of other machines, such as ventilators, pumps, &c.

AMMUNITION HOISTS OR LIFTS.

The adoption of electric agency for many motors upon men-of-war appears already of paramount necessity. The working of the great number of ammunition hoists which have become requisite through the ponderous modern armaments, with numerous guns, would necessitate a very large quantity of small but fast running steam engines, the service of which would unavoidably lead to a considerable increase of engineer hands. The installation of electric motors, driven from a central station, and requiring no particular attention and care, seems, therefore, advantageous for this purpose; the more so, as in special cases they are adapted to be fitted in very small dimensions, whereas a steam engine would always occupy a much larger space. If the ammunition supply is not effected by Paternoster appliances, but by lifts, the motors are, however, no longer so simple in their construction as those mentioned before. In the hoisting by lifts, the chairs have to be attached in such a way to the motor that the latter, at the ends of travel, is automatically stopped and set in motion. Besides, an electric brake must be provided, and by means of special minor appliances, the quiet starting of the chair must also be guaranteed. However, there are already numerous installations of this kind in existence, and their efficiency has been proved by

practical experience, from the results of which the general adoption of electrical energy for the ammunition hoists may be considered as secured in the near future.

GUN AND TURRET TURNING.

The manufacture of electrical turning appliances has lately occasioned a lively rivalry; yet, up to date, it cannot be asserted, without a doubt, that they will supplant the approved appliances of hydraulic force. Considering the paramount importance of these appliances for men-of-war, the fact that the question has been technically solved in the most complete manner does not only appear to be decisive, but every chance of the gear getting out of order must be practically excluded, and the crew, for this service, must be so completely familiar with its working that they are able not only to guarantee its expert handling and the maintenance of its efficiency, but also, in case of need, are able to repair and make good any damage. The current circuit in such installations must of necessity be very complicated, so that a quick detection of any sudden damage requires, in any case, considerable technical knowledge, especially with regard to the fact that faults in such electrical installations often, unlike those in mechanical appliances, do not show on the outside, but remain hidden in the circuit.

In consideration of the necessary shortness of this paper, I must deny myself the pleasure of entering more fully upon particular installations, and I will only state that, with parallel arrangement of the motors in one circuit current, thus avoiding a current of high tension, the connection with the general electromotor installation and their driving from the general central station can very well take place.

STEERING APPARATUS.

The steering apparatus offers the greatest difficulties for electrical application; but, on the other hand, this makes it one of the most interesting subjects.

Before going more closely into the matter of electrical application, I will shortly explain the steam steering gear hitherto in

use, in so far as it is necessary for the comprehension of the electrical appliances.

The steering gear with its appurtenances may be divided into three separate parts, viz., into the motor proper for working the rudder; into the arrangement of the motor for setting it in motion from the deck; and into the arrangements of the motor for stopping it after the rudder has been moved. In the steam steering apparatus, with mechanical appliance for setting it in motion, this is often done by means of a hand wheel, which is fixed on the bridge, and which is turned in correspondence with a scale for bringing the rudder into the desired position. The turning of this hand wheel turns at the same time a transmission system laid through the whole ship, and moves also, by means of a worm fitted to the end of the transmitting crank, a nut which is in connection with the steam inlet valve, and which thus opens it. By these means the motor proper is put in motion, and causes, by means of the turning of the motor crank, a self-acting return motion of the nut, and places the valve again into its position of rest. As soon, therefore, as the hand wheel on deck ceases to be turned, the motor will immediately stop itself through its own movement. Every shipbuilder, however, knows the great difficulties caused by the laying of such a long transmission system, which has to be worked by hand. Even although the mounting has been successfully completed, it will often happen, after the vessel has been running a short time, that the transmission can no longer be moved, a fact which is due to the contraction and expansion of the bulkheads and decks to which the blocks have been fixed.

With the electrical installation, the question is, whether the motor, or the moving appliance, or the stopping appliance alone, or the whole apparatus shall be driven electrically. As far as I am aware, the use of electricity for such an entire gear has hitherto not been attempted. In most cases electricity has only been employed for the starting appliance. A combination of the starting appliance with a self-acting registration upon the control board on deck by the electric current from the tiller has, however, proved to be so difficult, that, to judge from what has hitherto been achieved in this direction, we can hardly expect a so-

lution of this problem, at present, which will be satisfactory and always reliable in its action. As it stands to-day, this question allows only the installation of an electrical starting apparatus, which generally is restricted to a common governing apparatus, and which only supplies the current to a comparatively simple electrical apparatus, which, in its turn, again, controls the steam inlet valve. The closing of the valve must then be effected by cutting off the current by means of a separate indicator, with a hand showing the position of the rudder, which, in its turn again, is set in motion by the tiller direct. This apparatus may, again, be either mechanical or electrical, and several reliable electrical apparatus for this purpose are already in existence.

A very interesting starting appliance as used on the French cruiser *Bouvines* is described in the "Révue Maritime et Coloniale." Here the distributing valve of the steam steering apparatus is not automatically moved by the apparatus itself, but by a small electrical motor, quite independent of the steering gear, and the latter follows the movement of the valve. The starting of the motor is done from the deck by means of a governing apparatus. Here, however, the current is not led direct into the motor, but first to a relay, which then in its turn governs the motor current. The working of the governing apparatus on deck is effected according to a rudder indicator, which contains several numbered lamps. These different lamps correspond with certain rudder angles and are lit up by the movement of the tiller. Such lamp signals, which also are employed for engine telegraphs, have, however, the great disadvantage that the different signals, which are indicated by the simultaneous burning of different lamps, are difficult to distinguish in strong sunlight. It is also very misleading when the different lamps burn with different degrees of brightness, and a failing in consequence of a lamp burning out is also possible.

If the construction of an electric motor for the steering gear does not at the first glance seem to present any particular difficulties, these are indeed very material. A reversible motor requires a governing apparatus which must be of very substantial construction, if it is not to be speedily used up, or if undue heat-

ing of the same is to be avoided, regard being had to the size of the motor and to the fact that it may have to be worked, perhaps, 1,000 times in a day.

A continuously running motor, which only moves in one direction, requires again the insertion of electrical couplings for the turning of the tiller to the right and left. The suitability of such couplings for frequent in and out turning has, however, still to be demonstrated. The employment of two constantly moving motors, which work by means of a differential wheel appliance, demands the manufacture of very excellent wheels, if this apparatus is not to work too noisily. This latter machinery is at present in construction in Germany, and the result may be watched with great interest. However, all these contrivances have the disadvantage that they necessitate a very well trained personnel for their effective working and keeping in good order. If, therefore, as may with confidence be expected, electrical power is introduced on board ship to a greater degree, the special training of the crew in its use will be unavoidable.

CONCLUDING REMARKS.

At the close of my remarks I will only touch upon a general question, which is of importance for electrical installations on board. With the increasing employment of electricity on board ship, the question arises whether for such installations continuous or alternating currents should be chosen.

In all installations hitherto made, the continuous current has been exclusively used; it has proved completely efficient, and there has been no occasion to discard it, as long as there was only a question of illuminating the interior and of search lights. The latter can only be worked with continuous currents, otherwise their lighting power would suffer a decrease of about 40 per cent. As, on men-of-war, the consumption of energy for the search lights reaches the considerable extent of 20,000 to 70,000 Watts, it is evident that, for the kind of current required for lighting the interior, and for several small motors, continuous current can only be utilized. The injurious influences upon the compass may be avoided, with such a current, by careful disposition of

the conduits and the scientific construction and fitting up of the dynamo engines.

But when it comes to a general introduction of electro-motors for working the auxiliary machinery, and a central station is erected for this purpose, which, like one already in construction in Germany, works with a power of 300,000 Watts, the employment of continuous current offers considerable difficulties. In particular, the motors placed on deck for the gun turning apparatus and ship's winches have to be placed in such dangerous proximity to the compasses, that the disturbing of the latter, in the case of parallel current, can hardly be prevented. For the working of this machinery, therefore, the use of the alternating current becomes unavoidable, as such a current, and likewise any motor driven by it, has no influence upon the compass. This, however, again necessitates the erection of two central stations, viz., one for the search lights and lighting, with parallel current; and a second station, with alternating current, for driving the auxiliary machinery. Unfortunately this arrangement presents the great disadvantage that the motors for one station cannot be employed in support of, and in substitution for, those of the other, and that thereby a great complication would be created for the whole installation, which would demand greater capabilities from the crew. It will be impossible, however, to avoid this if the increased advantages, which the use of the electrical appliances affords on board of ships, are to be secured.

NOTES.

FULL POWER RUN OF THE U. S. S. *OLYMPIA.*

This cruiser, in commission on the China station, made a full power, natural draft, trial of four hours' duration on June 7, while on a passage from Hakodate to Yokohama, Japan.

The bottom was rough, the vessel having been last docked in December, 1895. The conditions of wind and sea were favorable and the machinery worked well.

An average speed of 19.94 knots was maintained. The speed was determined by frequent bearings on shore objects, the patent log readings being discarded as unreliable. The draught forward was 19.5 feet, aft, 23 feet 10 inches; the displacement being about 5,913 tons. It will be interesting to compare this run with the contract trial run, the data of which are given on page 256, Vol. VI, of the JOURNAL. The displacement and speed at that time were 5,586 and 21.686, respectively. The following are the principal data of the service trial: Steam pressure at boilers, 151.75, at engines, 144.25 pounds per square inch; vacuum, 26 inches; revolutions per minute, starboard, 124.83, port, 124.37; I.H.P., main engines, 11,492; estimated H.P. of all auxiliaries in operation, 340; total H.P., 11,822.

All six boilers were used, the total grate surface being 824, and the heating surface, 28,298 square feet. The combustion of coal per square foot of grate surface was 33.2 pounds per hour. The coal per I.H.P. per hour was 2.42 pounds.

THE RUN OF THE U. S. S. *PETREL.*

This single-screw gunboat of 892 tons displacement and 1,095 I.H.P., left Yokohama, Japan, on March 28, 1896, at 1·25 P. M., homeward bound to San Francisco, California, via Honolulu, Hawaiian Islands. The *Petrel* was described in Vol. I of the JOURNAL.

The vessel started with about 250 tons of Cardiff and 44 tons of other coal, a total of 294 tons, of which about 200 tons were carried in the bunkers.

The vessel started with one boiler, but the remaining boiler was connected about two hours later. She steamed with two boilers until 2 P. M., April 7, except that from 11 A. M., April 2, to 6·30 P. M., April 3, fires were out in one boiler. On April 5, second day, fires were banked in both boilers and the ship hove to in a heavy sea until 2·30 P. M., April 6. During this time the engines were stopped about twenty-four hours. From April 7 to April 11, 6·10 P. M., one boiler was used. Two boilers were used during the remainder of the run. The vessel arrived at Honolulu at 7·30 P. M., April 13, having on board about 86 tons of coal. The dynamo was run about twelve hours each day; the vessel was heated and water distilled during part of the voyage.

Total steaming time 391.7 hours, or about 16.3 days; distance from Yokohama to Honolulu 3,450 nautical miles; average speed, 8.8 knots; total coal burned, 208 tons; coal consumption for all purposes, per steaming day, 12.75 tons. Average revolutions, about 82 per minute.

On April 22, 6·30 A. M., the *Petrel* left Honolulu under both boilers, having on board about 260.5 tons.

On May 1, at 8·45 A. M., she arrived at Sausalito, California, opposite to San Francisco, having on board about 93 tons. Dynamo and distilling as before.

Total steaming time, 212.75 hours, or about 8.86 days; distance from Honolulu to San Francisco, 2,090 nautical miles; average speed, 9.8 knots; total coal burned, 167.5 tons; coal consumption for all purposes, per steaming day, 18.89 tons; average revolutions, about 99.2 per minute.

On the run from Yokohama to Honolulu, the engines were stopped for 1½ hours, on account of the nut and gland of the L.P. piston rod stuffing box working off; 10 minutes to try sail power, and about 24 hours while the vessel was hove to. From Honolulu to Sausalito the engines were stopped 62 minutes on April 23, to renew gasket of inboard drain cock on H.P. cylinder; 1

hour and 11 minutes, to replace gland and nut on L.P. piston rod stuffing box, which had worked off; and 1 hour and 17 minutes on April 28–29, on account of a broken stud in air pump.

Considering the size of the vessel and the fact that she has compound engines, the results of this long voyage are very creditable.

COMBUSTION TESTER ON THE ITALIAN BATTLESHIP *SICILIA*.

["Engineering," London.]

In seeking to obtain the best results from the combustion of fuel, the data furnished by a study of the chemical constituents of the gases produced by combustion, permit of accurate calculations being made as to the percentage of loss of heat, and also give approximately an idea of the best way of reducing these losses to their minimum point. In Germany especially, the study of the gases in the funnel has absorbed the attention of many eminent engineers and professors, and during the last two years a large number of interesting experiments have been carried out and their results tabulated.* In France also, some steps have been taken in the same direction in connection with the combustion of fuel in the boilers of locomotives by Mons. Henry, of the Paris and Mediterranean Railway Company.† In our own country most of such experiments have been made with land boilers.

It is well known that to insure the greatest efficiency with the greatest economy it is necessary to proportion the admittance of air to the burning fuel, so that the latter may get just as much as it requires under the different circumstances, and also that this proportion can in no way be ascertained and regulated from an observance of the density or otherwise of the smoke, as the vary-

*See Protokoll der 23 Delegirten und Ingenieur Versamlung, 1894, page 65.—Bericht ueber die Sitzung der Commission zur Prüfung und Untersuchung von Rauchverbrennungs Vorrichtungen. Berlin, 1894.—Experjments of Walter Hempel and Lewicki. Zeitschrift für Angewandte Chemie, 1895, page 729.

† See Etude expérimentale de la Vaporisation dans les Chaudières des Locomotives. A. Maulde, Paris, 1889.

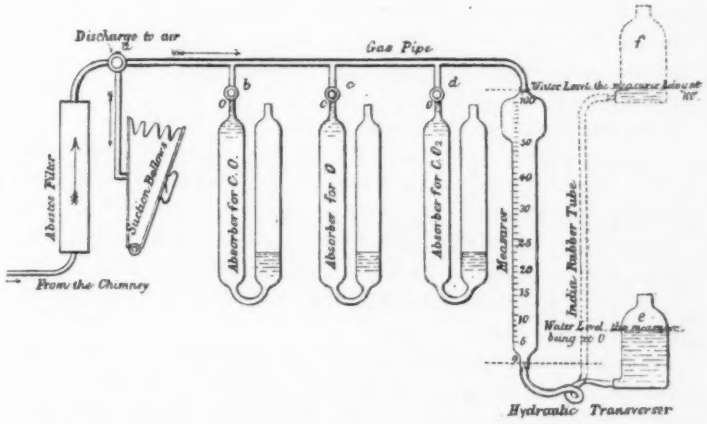
ing denseness of the smoke gives by no means an accurate idea of the relative efficiency of the combustion.

The full acceptance of this point naturally carries with it the necessity of a special means of ascertaining the exact composition of the gases discharged from the funnel. This investigation was formerly carried out by chemical methods, but the process has now been so simplified and facilitated by the introduction of physical means, based on the principle of Archimedes, that it establishes with sufficient accuracy the principal thing necessary to be known, namely, the percentage of CO_2 present in the gases in the funnel. In large plants on land, the advantage of having such an apparatus permanently fitted has repeatedly manifested itself, and it is being largely adopted on the Continent in sundry forms; in France the balance of Meslans and Frère is principally used, whereas in Germany and Belgium the dasimeter of Dürr and Siegert and the econometer of Arndt are preferred.

It was, therefore, presumed that a similar method of examination of the funnel gases could not fail to be of considerable service during the trials of machinery of such a vessel as the *Sicilia*, and that not only would the result be interesting from the theoretical point of view, but also be of considerable practical service, as by its means it could at once be determined whether more air was passing through the fires than was necessary, and, inversely, therefore, if sufficient coal was being kept on the bars at the back of the grates, a matter of very considerable importance in such trials, and one very difficult to realize with Navy boilers of present construction, with their long grates. This difficulty is especially felt with firemen of the Italian Royal Navy, who are not so trained as to acquire the skill and force in their arms necessary to throw the coal well to the back of the furnaces, and are obliged to use the rake to distribute the coal over the grate.

With this end in view, Dr. Ludovico Peroni, director of chemistry in the works of Messrs. Ansaldo, suggested the adoption of the Orsat apparatus for testing gases, as physical methods were not applicable, owing to the oscillation of the vessel. This appliance was fixed on the upper deck, a piece of gas tubing of $\frac{3}{4}$

inch diameter being led into each of the three funnels, standing horizontally across the funnel as far as the center; the end of this tube was stopped up, and the gases entered by means of 40 holes of $\frac{1}{16}$-inch diameter in the bottom of the pipe. In this way a portion of the gases for analysis could be obtained, without any change or any admixture of air, on its way to the apparatus. The gas was drawn through this tube by means of a small bellows, and then, after passing through an asbestos filter, which retained all solid substances, such as rust, &c., passed into the measuring chamber and the various absorbers of the Orsat apparatus by means of cocks suitably disposed.



The arrangement of the apparatus is shown in the figure, and the method of operation was as follows: The level of the liquids in the absorbers being brought to zero, as shown in the diagram, by means of handling the transverser, the cocks are shut, and the transverser which was first filled with water in the position *e*, is raised to the position *f*, so that the water fills the measuring chamber to the mark 100. This done, after the air in the pipe has been extracted by means of the bellows, and discharged through the four-way cock *a*, this cock is opened to give a free horizontal passage, and the transverser being lowered, the water flows into

it until it stands in the measurer at zero, and the cock *a* is then closed; you have then 100 volumes of the gas ready for analysis. The transverser is then raised, but the cocks being shut, the gas can not leave the measurer, but becomes compressed in it. The cock *d* is then opened, and the pressure of the water forces the gas into the chamber containing caustic potash, the absorber for carbonic acid, and as the gas is absorbed, the water in the measurer slowly rises. As soon as the level is stationary, showing that there is no more gas to be absorbed, the transverser is lowered until the level of the liquid in the absorber is again at zero. The cock *d* is then closed and the transverser further lowered until the level of water in it is exactly the same height as the level of the water in the measurer, when it will be found to go to, say, 15, showing that fifteen-hundredths of the funnel gas have been absorbed by the caustic potash, or, in other words, that fifteen-hundredths of the funnel gas consisted of carbonic acid.

The apparatus is now ready for the second part of the operation. The transverser is raised, the cock *c* opened to the central chamber containing pyrogallate of potash as the absorber for oxygen, and when this operation is completed as before, the water in the measurer will stand at, say, 20, showing that a further 5 per cent. of the funnel gas has been absorbed which consisted of oxygen.

A similar procedure is gone through with the third absorbing chamber, which contains ammoniacal chloride of copper, to absorb the carbonic oxide, and the final level in the measuring chamber will probably go to 23, the remainder of the funnel gas consisting of nitrogen.

The operation being completed, to recharge the apparatus, the transverser is raised to its original position *f*, the cock *a* is opened to the air, permitting the nitrogen to escape, and after clearing the pipes with the bellows, the cock *a* is set so that the funnel gas can again pass into the apparatus as before. In order to reduce the time necessary for the operation as much as possible, the absorbing chambers contain a number of small tubes, so that there is a considerable surface of the absorbing liquid to act upon the gas as it enters.

It should be noted also that the water in the measuring chamber is acidified with hydrochloric acid to the extent of two per cent., so that it thereby loses its property of absorbing carbonic acid. In order that the results may be as relatively exact as possible, the measurer is kept in water, so that the temperature may be the same throughout.

This operation was continually performed throughout the trial, and each time that the quantity of CO_2 in the gases discharged was shown to be too small, notice was sent below to that particular boiler room, when an inspection of the furnaces invariably showed that some of them were short of coal at the backs. On every occasion that the defect was noted and the coal pushed to the backs of the furnaces, there was a material difference in the production of steam in that compartment.

It is interesting to note how the steam pressure and horsepower developed vary almost in direct proportion to the efficiency of the combustion. As will be well understood, it is too much to suppose that the observations so made with this apparatus on such a trial would be absolutely exact, when it is remembered that the gases in each funnel are coming from six boilers, but nevertheless the experience gained definitely proved the value of such an experiment, and this method would certainly be most useful as a means of comparing the efficiency of different arrangements of uptakes and funnels. With water tube boilers of the Belleville type, it is the practice to carry the division of the uptakes well up into the funnel itself, so if a test pipe were led into each of these divisions, and connecting pipe conveniently arranged from it to the testing apparatus, it would form an admirable method of determining the best arrangement of combustion chamber, and of baffle plates amongst the tubes in water tube boilers, a much debated point at the present moment, when one of the charges brought against the water tube boiler is that it is not so economical as the ordinary return tube boiler.

NOTE.—The results of the trials of the *Sicilia* were given on page 410 of the May number. Another convenient form of combustion tester is patented by Mr. George Craig and made by Messrs. Baird and Tatlock, Glasgow. In a letter to Dr. Perroni, (Rivista Marittima, June, 1896, page 528), and referring to an extra registering mechanism which has been added to their apparatus, so as to admit of prolonged trials, the makers state that Craig's tester is now admirably suited for work on steamers.—EDIT.

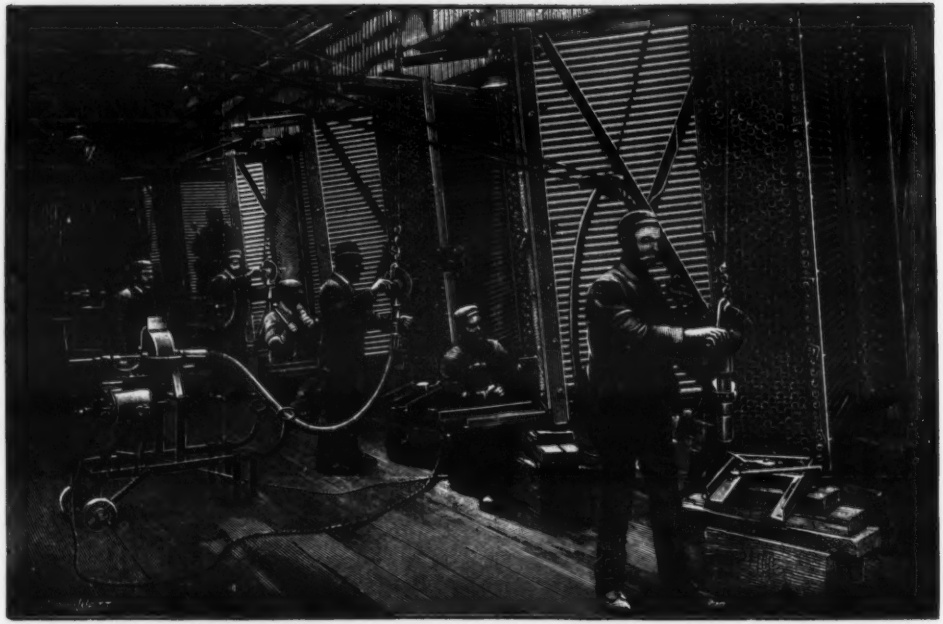
THE RUNS OF THE *ST. PAUL* AND *ST. LOUIS*.

The Southampton-New York record was broken by the American Line steamer *St. Paul* on her trip in June. She covered 3,113.7 nautical miles in 6 days, 5 hours and 32 minutes, thus eclipsing the *New York's* record of 6 days, 7 hours and 14 minutes. The *St. Paul* arrived here on Friday, and her average hourly speed on the entire trip was 20.82 knots; part of the time she went along at the rate of over 21 knots an hour. The following table will show the various distances traversed each day of the voyage:

	Distance.	*Lat.*	*Long.*
May 30 left Southampton 12 noon.			
May 31	487.8	49.48	14.01
June 1	521.9	48.33	27.11
June 2	521.7	45.51	39.17
June 3	513 0	42.38	50.13
June 4	508.6	41.46	61.20
June 5	518.9	40.36	72.50
	41.8	To Sandy Hook.	
	3,113.7		

Had the *St. Paul* taken the short course of 3,043 knots, as did the *New York* when she made, in September, 1894, what has been the record up to the present time, she would have lowered it still more. Last month she made the trip over the long course of 3,112 knots in 6 days 9 hours and 5 minutes, but was delayed on this voyage 12 hours and 14 minutes on account of fog. The present trip is the tenth round trip of this vessel. The average number of revolutions of both port and starboard propellers was 89½, except for one day, when the average revolutions were 93.1 per minute and distance steamed 521.9. The steam pressure was 200 pounds to the inch, and the average daily consumption of coal was 310 tons.—("Seaboard," New York.)

The above record-breaking run of the *St. Paul* has, however, just been surpassed by the notable performance of the *St. Louis*, which arrived in New York on August 7. The passage was made in 6 days 2 hours and 24 minutes, at an average speed of 20.86 knots. The average number of revolutions was 89.5 per minute for the starboard and 89.7 for the port engine. The slip



EXPANDING TUBES IN YARROW BOILERS.

of propellers was 13.9 per cent., and the coal consumption, 340 tons per day. The daily runs were 477, 519, 530, 520, 510, 499, a total distance of 3,055 knots.

THE YARROW BOILERS.

At the time of the spring meeting of the Institution of Naval Architects, Mr. Yarrow gave a description of the system of expanding tubes adopted by his firm and of certain features of construction in their boilers. The accompanying illustration, kindly supplied by Messrs. Yarrow & Co., shows the system in operation of expanding tubes by means of steam and electric power, and gives an idea of the expander itself. By these methods thirty tubes can be expanded per hour, or about three times as many as by hand.

The first man on the right is shown using steam power, conveyed from the shop shafting by means of the rope belting and flexible shaft; on the next boiler, an electric motor, shown on the left, turns the flexible shaft and the expander.

The body or annular part of the expander, and which contains the rollers, is made to revolve by the gearing shown, leaving the mandrel to feed itself. This method of feeding does away with all hammering during the expanding. The arrangement of having the body turn is made necessary by the fact that the mandrel could not be made strong enough to stand the twisting stress of the rapid expanding.

The rollers are set at a slight angle to the axis of the mandrel, so that they draw themselves inwards during the work. No drifting is required. The larger size of the extreme tube end is secured by the relative taper of the mandrel and the rollers. There is an automatic stop to prevent over expanding. It is possible with this description of mandrel to work on very small tubes, and Messrs. Yarrow are now expanding one end of condenser tubes no more than $\frac{1}{2}$ inch in diameter, the mandrel being more like a big knitting needle than part of a tube expander.

The operation of renewing a tube in this boiler was next explained. The tubes in front of the burst one are removed, which

EXPANDING TUBES IN YARROW BOILERS.

may be done in the reverse manner to the way in which new ones are replaced. The tube is first inserted into the first hole in the steam drum and passed upwards into it; it is then lowered into the first hole in the water chamber below; then passed up again into the next hole in the steam drum, then brought down again into the next hole in the lower tube plate, the tube being thus zigzagged into the position required. With a boiler in place on board, a burst tube in the middle of the nest could be replaced, together with the other tubes required to be removed to make way for it, and the boiler be ready for steaming within a space of two hours after the boiler was cold. The time for emptying and cooling should be added. The upper end of the tube is expanded in the usual way from the inside of the steam drum. The lower end can be expanded in the same manner if the water pocket is sufficiently large to admit of a boy working in its interior, but if the water pocket is too small for this, the expander is placed opposite the tube and the mandrel of the expander is driven round by means of a jointed bar inserted from the steam drum.

Mr. Yarrow then showed the latest system adopted by his firm for automatic feed, the description of which is taken from London "Engineering." He pointed out that in feeding water tube boilers a class of construction different altogether from boilers of the old style had to be dealt with. In the case of water tube boilers, with the internal pressure in the tube, there is far more probability of a large escape of water than in boilers where the pressure is one of compression on the tube. If a group of boilers is supplied with water from a common source, in the event of a tube bursting in one boiler, the demand upon the pump to maintain the water level in the remaining boilers of the group, and to supply water to the boiler in which the tube has burst, would be in most cases far in excess of the capabilities of the pump.

For these reasons Mr. Yarrow gave the preference to a single pump to each boiler, rather than to having a group of boilers supplied from the same pump. Further, the separate feed system offers the opportunity for adopting a method of automatically

feeding the boiler in a remarkably simple manner. He thought it would be admitted that any apparatus for automatically regulating the supply of water ought to be most certain in its action and capable of being relied upon absolutely, because, if there is no automatic feed, the stokers will be constantly watching the water level, while if such an apparatus be fitted, the stokers will naturally neglect to do so. Should the gear fail to work on one occasion, it might not be discovered until too late to avoid a serious accident; therefore, simplicity for an automatic feed was one of the first considerations. The arrangement here described is one which, as yet, Mr. Yarrow has only tested on a small scale, in a boat having engines of 300 horse-power. So far as it has been tried, it has proved to be quite successful, but whether this would continue true when it is used on a larger or smaller scale remains still to be proved. In the center of the length of the steam drum is placed an inverted cone, in which there are a few holes, to insure the water level in the interior of the cone being the same as on the outside of it. By confining a part of the water in the drum within the cone, violent ebullition of that part is prevented and a steady water level obtained. The donkey steam pipe is led down into the cone and ends near the water level. So long as the water is below the steam inlet, the donkey will work and pump up the boiler. So soon as the water rises to the level of the orifice, water, instead of steam, will find its way into the steam pipe, and will greatly check the speed of the pump, but not entirely stop its working. Under these conditions, the pump, instead of pumping water into the boiler, will actually be the means of drawing water out of it, because the steam cylinder is of greater capacity than the pump cylinder, and the difference between the two will be a measure of the water that the pump draws from the boiler at each stroke. This system, it is claimed, not only enables water to be pumped up if it fall too low, but the water level is lowered automatically if it be too high. A means has been adopted of raising and lowering the donkey steam pipe, so that any height of water level may be secured that would be found most suitable.

For a description of the above arrangement, as fitted on torpedo boat destroyers, see under Ships, Argentine Republic.

AUTOMATIC SAFETY STOP VALVES ON THE *TEXAS*.

Owing to a change made in the location of the hydraulic pumps, from the compartments below the protective deck (as described on page 91 of the February number) to the redoubt, it became necessary to lead the steam pipes to these pumps above the protective deck. To prevent loss of life, in case of an accident to or rupture by shot of these pipes, two 5-inch automatic safety stop valves, made and patented by the Foster Engineering Co., Newark, N. J., were fitted. One of these valves is placed on each side of the vessel, near the junction of the branch leading to the pump with the auxiliary main, and below the protective

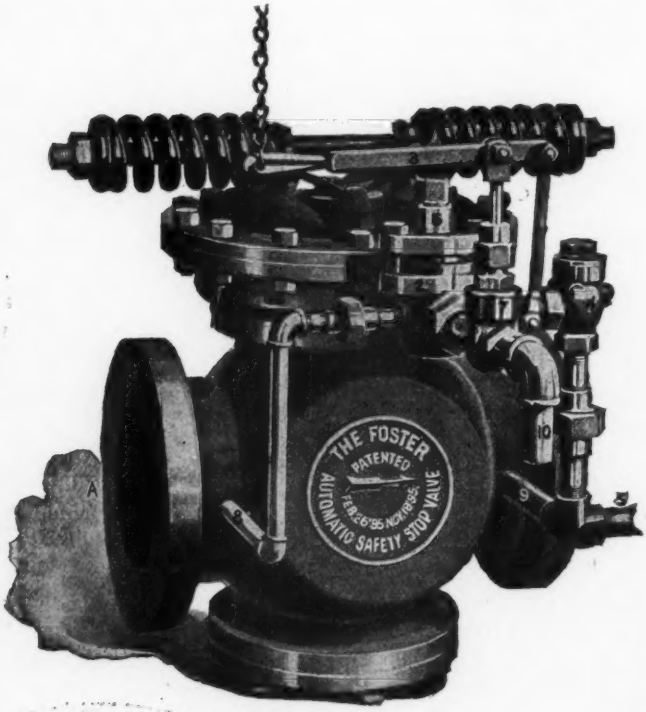


FIGURE 1.

deck. The branch pipe then passes up through the armored tube to the bottom of the turret, then runs under the main deck to the side of the ammunition hoist and from there up to the redoubt. The part of the pipe running under the main deck is covered with 2-inch armor.

A half tone of this valve is shown in figure 1, which is a modification of the usual ones, made by the same company, in the arrangement for operating the main valve. In place of the piping from the main steam pipe and the auxiliary valves, *1* and *6*, in

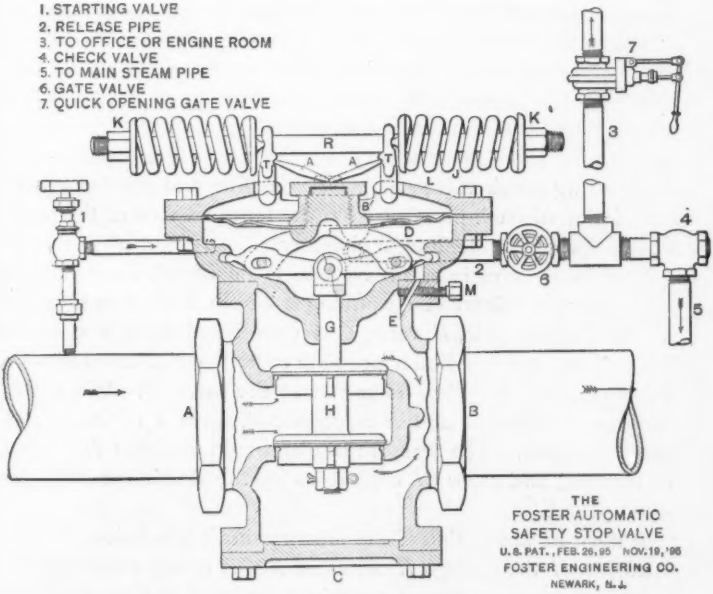


FIGURE 2.

figure 2, a four-way plug cock, *2*, figure 1, is substituted. With the plug in one position, steam is admitted from the initial side of the valve to the diaphragm chamber; in the reversed position, steam is shut off from the initial side and allowed to flow to the lever gate valve, *7*.

AMERICAN SOCIETY OF NAVAL ENGINEERS.

By reference to figure 2 and the following description, the working of the valve, as usually installed, will be seen. The valve, in its general construction, is similar to the Foster Pressure Regulating Valve, class W, except that its action is down instead of up. The main valve *H* is balanced and its action controlled by the steam pressure on the delivery side, which tends to keep it open, and the reaction of the two springs, *K*, *K*, which tends to close the valve. A ¼-inch pipe, with valve *1*, leads from the boiler, or initial side *A* of the valve, to the diaphragm chamber *D*, and a ½-inch pipe, with valve *6*, leads from *D* to the atmosphere—lever gate valve *7* being interposed—or to the main or auxiliary steam pipes in any part of the ship. In case of an accident necessitating the immediate stopping of the engines, or the shutting off of steam in the main pipe, valve *7* can be opened instantly by means of suitable mechanical or electric connections between its lever and the engine rooms, or other places. An angle swing check valve *4* is placed on pipe *5* to prevent an accumulation of back pressure from the terminal side of the main steam pipe in the diaphragm chamber.

Normally, the main steam valve *H* is closed. To open it and allow the full volume of steam to pass from the boiler side, *A*, to the delivery side, *B*, valve *6* is closed and valve *1* opened. This allows the full boiler pressure to act on the under side of the diaphragm and thus raise it and the valve *H*. When the pressure in pipes *A* and *B* is equalized, valve *1* is closed and valve *6* opened. The pressure in diaphragm chamber *D* is then maintained, and valve *H* held open by the steam entering the small port *E*.

It must be noted that if the pressure in *D* falls below the adjustment of the springs *K*, *K*, valve *A* will close; consequently these springs are adjusted to resist a pressure of from 20 to 30 pounds below the minimum pressure carried.

If, therefore, the pressure in *D* is suddenly reduced by opening gate valve *7*, producing an effect similar to the bursting of the steam pipe or any of its connections, the reaction of the springs will immediately close valve *H*.

A 2½-inch valve was satisfactorily tested at the New York

Navy Yard with a boiler pressure of 90 pounds, and the springs set to close at 50 pounds per square inch. Numerous trials were made, all of them showing the quick and perfect action of the valve. When gate valve 7 was gradually opened and the pressure in *D* thus reduced, the flow of steam through *H* was steady, until the pressure reached 50 pounds, when the valve closed completely and shut off the steam from the delivery side. When the gate valve was opened suddenly the flow of steam ceased immediately.

The 5-inch valves for the *Texas* were similarly tested and worked perfectly.

SHIPS.

UNITED STATES.

New Battleships and Torpedo Boats.—By the Act of Congress, approved June 10, 1896, provision was made for the construction by contract of three sea-going coast-line battle ships designed to carry the heaviest armor and most powerful ordnance upon a displacement of about 11,000 tons, to have the highest practicable speed for vessels of their class, and to cost, exclusive of armament, not exceeding $3,750,000 each; three torpedo boats to have a maximum speed of not less than thirty knots and to cost in all not exceeding $800,000; and not more than ten torpedo boats to cost in all not exceeding $500,000, and to have the highest practicable speed for vessels of their class. Not more than two battle ships and not more than three torpedo boats shall be built in one yard or by one contracting party.

All vessels are to be built under the provisions of the Act of August 3, 1886, as to materials for hulls, engines, boilers, etc., except that no premiums are to be offered, and that all parts shall be of domestic manufacture. One battleship and three torpedo boats are to be built on the Pacific side, for which an addition of 4 per cent. to the lowest accepted bid for the other vessels is allowed; one torpedo boat on the Mississippi and one on the Missouri River; and one torpedo boat on the Gulf of Mexico. If these vessels can not be built at the above-mentioned places at a fair cost, they may be built elsewhere. The contracts for the construction of the vessels must be made before October 8, 1896.

Sea-going Coast-line Battleships Nos. 7, 8 and 9.—Proposals for these vessels will be invited under Class I, on the plans and specifications prepared by the Navy Department, and under Class II, on the bidder's plans and specifications. All designs submitted must be in such detail, accompanied by such plans, specifications and calculations, as to enable the Navy Department to readily determine its value and strength and whether it fulfills the below-mentioned general requirements.

In determining whether cost is above or below the limit, there is included in the cost of armament, besides the guns, ammunition, etc., all armor protecting directly guns and loading positions, such as turret and barbette armor, casemate armor protecting guns, etc.

The following elements and qualities are obtained and provided for in the Department's design, and their equivalent must be obtained and provided for in all designs submitted:

Length on load water line, normal displacement, feet	368
Moulded breadth at load water line, feet	72
Mean draught at normal displacement, feet	23.5
Normal displacement, about, tons	11,500
Total coal capacity, loose stowage, tons	1,200

The average speed to be maintained at sea for four consecutive hours will be not less than 16 knots. The hull will be of steel, not sheathed, with double bottom and close water tight subdivision. The arrangements of decks above water will provide ample freeboard and berthing accommodations. There will be two military masts with fighting tops. The hull about the water line will be protected by an armor belt of a maximum thickness of not less than 16.5 inches and a mean depth of 7.5 feet. This belt will extend from the stem to the after barbette, and will have the maximum thickness throughout the engine and boiler spaces; from thence forward it will taper gradually to a uniform thickness of 4 inches. The transverse armor at the after end of the belt and just forward of the boilers will be 12 inches thick. Barbettes for 13-inch guns will have 15-inch armor, except in the rear where it will be 10 inches.

The turret armor will be 17 inches thick in front, and 15 inches elsewhere. The ship's side, from the armor belt to the main deck, will be protected by $5\frac{1}{2}$ inches of steel armor, from barbette to barbette, with coal behind a part of this casemate armor.

A protective desk will extend throughout the length of the vessel, the flat part being $2\frac{3}{4}$ inches, and the inclined sides, 3 inches thick forward and 5 inches aft. There will be a cellulose belt around the whole vessel.

A conning tower 10 inches thick, having an armored communication tube 7 inches thick, will be carried in a commanding position forward, the tube extending to the armor deck and affording protection to the voice tubes, bell wires, &c. An additional armored station will be fitted aft having armor not less than 6 inches thick. In wake of the 6-inch guns on the main deck, there will be continuous armor 5½ inches thick extending between the turrets. Further protection will be afforded by 1½-inch splinter bulkheads between the guns, extending from deck to deck. The 6-inch guns on the upper deck will be similarly protected, and the smaller guns by shields and extra side plating.

The armament will consist of four 13-inch B. L. R.; fourteen 6-inch, sixteen 6-pounder, and four 1-pounder rapid fire guns; four machine guns; one field gun, and four broadside torpedo tubes, two on a side.

The engines will be of the twin-screw, vertical, triple-expansion type, in two compartments.

The boilers will be single ended, eight in number, and placed in four compartments.

Any alternate design of machinery submitted by bidders must fulfill the general requirements contained in the Specifications for Machinery issued by the Bureau of Steam Engineering. Such design must be accompanied by specifications in sufficient detail to enable the strength of the principal parts, and the probable efficiency of the whole design, to be readily determined; and calculations showing in detail the total weight and position of center of gravity of all machinery, the weight not to exceed 1,133 tons, if it is proposed to adopt the Department's design of hull.

The electric lighting plant will consist of three units, each unit having engine, dynamo and combination bed plate, and each dynamo having a rated output of 400 ampères at 80 volts. The total weight of the three units complete must not exceed 31,500 pounds, and of the whole electric installation, including dynamos, engines, bed plates, all fittings, wirings and stores, and four search lights, not over 50 tons.

PRINCIPAL WEIGHTS CARRIED.

Ordnance and ammunition, tons	987
Torpedo outfit, stores and equipment, tons	25
Machinery, complete, with water and stores, tons	1,133
Equipment weights, including electric plant, tons	175
Turret turning machinery, complete installation, tons	90
Boats and outfit, tons	24
Masts and spars, tons	40
Officers, crew and effects, tons	75
Provisions and clothing, tons	125
Miscellaneous stores and water, tons	85

Complement of officers and men (about), 490.

Two-thirds of total coal plus two-thirds of full ammunition, plus two-thirds of total stores, must be carried at the normal displacement of 11,500 tons.

If, on trial, the average speed equals or exceeds 16 knots, the vessel will be accepted; below 16 and over 15 knots, the vessel will be accepted at a reduced price, the reduction being at the rate of $25,000 for every quarter knot below 16 and above 15½ knots, and at the rate of $50,000 per quarter knot between 15½ and 15 knots. If the speed falls below 15 knots, the vessel will be rejected, or accepted at a reduced price to be agreed upon.

30-Knot Torpedo Boats.—For these, the Navy Department has invited proposals for the construction of the hull, machinery and equipment, complete in all respects, in accordance with the plans and specifications provided by the bidder.

The following elements and qualities must be obtained in the designs submitted:

The average speed, maintained for one hour, must not be less than 30 knots.

The boats are to be built and fitted complete for sea by the contractors, with the exception of sea stores and of the ordnance and ordnance outfit of all kinds, which, however, will be fitted and secured in place by the contractors. The dimensions, weight and approximate cost of ordnance appliances to be supplied by the Government are given in detail.

Two conning towers will be placed in convenient positions, one forward and the other aft. The spaces allowed for torpedo

tubes, torpedoes and appurtenances and rapid firing guns are to be shown on the plans of designs submitted. Accommodations will be provided for four commissioned officers and an adequate crew. An incandescent electric lighting plant must be fitted, but no search light will be required. Bidders must specify the weights, additional to that of complete hull and machinery, that they propose to carry on trial, also the total coal capacity of bunkers.

The general requirements for the machinery are as follows:

The boilers and all steam pipes and valves subjected to boiler pressure will be tested to a pressure 110 pounds in excess of the designed working pressure; the high pressure cylinders and valve chests to the same pressure; the intermediate cylinders and connections, if a triple-expansion engine is used, to 70 per cent. of the boiler pressure (if a quadruple-expansion engine is used, the intermediate cylinders and connections to 80 and 60 per cent. respectively of the boiler pressure); the low pressure cylinders to 90 pounds; the exhaust side of the low pressure cylinders, and the condensers to 30 pounds pressure.

The screw propellers will be of manganese bronze. The boiler tubes will be of the best charcoal iron, those nearest the fire No. 10, and the others No. 12 B.W.G. in thickness. All bolts and nuts will conform to United States Navy standard. There must be an evaporating plant of 3,000 gallons' capacity in 24 hours for supplying fresh water for the boilers, and a distiller for making drinking water; also tanks of 1,600 gallons' capacity for holding fresh water for the boilers. A set of wrenches will be furnished to fit the nuts on all removable parts of the machinery. Drawings, on tracing cloth, of the machinery as completed will be furnished the Bureau of Steam Engineering.

The machinery shall, during manufacture, be subject to inspection by an engineer officer appointed by the Government, who shall have power to reject any material that fails during working, or that is so weakened by flaws or imperfections of any kind as to render it unfit for the purpose intended.

The plans submitted with bids must be accompanied by specifications and an estimate of the weight of machinery.

All designs submitted must be accompanied with complete plans and specifications for building, and such calculations of weight, displacement and stability as will demonstrate the satisfactory strength and stability of the whole structure. If bidders desire to modify the specifications for steel material prepared by the Navy Department, they must submit with their bids a full statement of the modifications proposed.

If, on trial, the average speed equals or exceeds 30 knots, the boat will be accepted in so far as the speed is concerned. In case of rejection, any money that may have been paid to the contractors on account shall be refunded.

Torpedo Boats to cost not over $500,000.—The exact number, size and speed of these boats not being fixed in the Act of Congress, the Navy Department will entertain bids for boats of two separate types, and has invited proposals as follows, provided that the total cost of the boats, including ordnance, which is, however, not to be supplied by the bidder, shall not exceed $500,000.

TYPE NO. 1.

Class 1.—For the construction of the hull and machinery, including engines, boilers and appurtenances, and equipment, complete in all respects, in accordance with the plans and specifications provided by the Secretary of the Navy.

Class 2.—For the same, in accordance with the plans and specifications provided by the bidder.

Bidders may adopt the plans and specifications of the Department for the hull or machinery or any part of either, and embody them in their plans and specifications.

The following elements and qualities must be obtained in the designs:

The average speed, maintained for two consecutive hours, must not be less than twenty knots.

The boats are to be built and fitted complete for sea by the contractors, with the exception of sea stores and ordnance and ordnance outfit of all kinds, as has been mentioned for the 30-knot boats. Conning towers and accommodations for two officers and a crew will be the same as for the other torpedo boats.

The freeboard forward to be not less than 4.25 feet. The spaces allowed for torpedo tubes, the torpedoes and appurtenances and rapid firing gun must be shown on the plans submitted.

The boat on trial must carry the following weights additional to that of the completed hull, machinery and spare parts: Torpedoes and gear, rapid firing guns and ammunition, $3\frac{1}{2}$ tons; coal, 5 tons; crew, boats, equipment, &c., 4 tons; total, $12\frac{1}{2}$ tons.

The coal capacity must be at least 16 tons of 43 cubic feet per ton.

Complete plans and specifications must be submitted, and bidders may modify the steel specifications, as mentioned above for the 30-knot boats.

The designs of machinery submitted must fulfill the following general requirements issued by the Bureau of Steam Engineering:

105-FOOT BOATS.

Class 1.—The Department's design for the machinery consists of a single-screw triple-expansion engine of about 850 I.H.P., steam for which is supplied by two water tube boilers. The general dimensions of the engines and boilers, and the material of which the different parts are made, are shown on blue prints, which will be furnished by the Bureau of Steam Engineering. The weight of machinery must not exceed 25 tons.

Bidders will be allowed choice of water tube boilers provided they will guarantee their performance for a period of two years from date of acceptance of boat. If a boiler fails within the guaranteed time, the builder must supply another, without delay, of a different type, if so directed by the Department, provided the failure of the first boiler is not due to carelessness on the part of the Government or injury received in action.

All materials used in the construction of the machinery and appurtenances must be of the very best, and the workmanship must be first class in all respects. All bolts and nuts will conform to United States Navy standard. The screw propellers will be made of manganese bronze. A complete set of drawings of the machinery as fitted will be furnished.

The boilers and all steam pipes and valves connected therewith

will be tested to a pressure of 360 pounds, the H.P. cylinder and valve chest to 360 pounds, the I.P. cylinder and connections to 180 pounds, the L.P. to 90 pounds, the exhaust side of L.P. valve chest, the exhaust pipe and the condenser to 30 pounds.

The steel material for machinery must conform to the requirements of specifications for the inspection of steel for use in the construction of the hulls and machinery of torpedo boats Nos. 9, 10, 11, et seq. Manganese bronze must have a tensile strength of at least 55,000 pounds per square inch, with at least 20,000 pounds elastic limit, and an elongation of 20 per cent. in 2 inches. Boiler tubes must be made of the best charcoal iron and must conform to the specifications of the Bureau of Steam Engineering. Air and circulating pumps will be made of composition. A set of wrenches will be furnished to fit the nuts on all removable parts of the machinery.

The machinery shall, during manufacture, be subject to inspection by an engineer officer appointed by the Government who shall have power to reject any material that fails during working, or that is so weakened by flaws or imperfections of any kind as to render it unfit for the purpose intended.

Class 2. Bidders must follow the general design of the Department's machinery so far as material is concerned, which will be subject to the same inspection and tests as specified for Class 1.

Boiler tubes will be of the best charcoal iron, those nearest the fire No. 10, and the others No. 12 B. W. G., in thickness. All bolts and nuts will conform to United States Navy standard. A set of wrenches will be furnished to fit the nuts on all removable parts of the machinery. A complete set of drawings, on tracing cloth, of the machinery as completed will be furnished the Bureau of Steam Engineering.

The plans submitted with bids must be accompanied by specifications and an estimate of the weight of the machinery.

The general dimensions, approximate only, of type 1, are:

Length on load line, feet	105
Beam on load line, feet	12½
Mean draught, feet	4½
Displacement, about, tons	68
I.H.P., about	850
Speed, knots	20

Armament.—Two single deck torpedo guns; one 1-pounder rapid firing gun; two automobile torpedoes; 180 rounds 1-pounder ammunition; total weight, 3½ tons.

If, on trial, the average speed equals or exceeds 20 knots, the boat will be accepted; if below 20 and over 19 knots, the boat will be accepted at a reduced price, the reduction being at the rate of $10,000 per knot below 20 knots. If below 19 knots, the boat will be rejected, or accepted at a reduced price mutually agreed upon.

TYPE NO. 2.

Proposals are also invited for boats of this type under Class 2. The general requirements are the same as for type No. 1, with the following exceptions.

The average speed to be maintained for two consecutive hours must not be less than 22½ knots; there must be accommodations for four officers and crew; the additional weight to be carried on trial will be 20 tons; and the coal capacity must be at least 25 tons.

The machinery requirements are the same, except that, in addition, there must be an evaporating plant of 900 gallons' capacity in 24 hours for supplying fresh water for the boilers, and a distiller for making drinking water; also tanks of 400 gallons' capacity for holding fresh water for the boilers.

The general dimensions, approximate only, are as follows:

Length on load line, feet	140
Beam on load line, feet	14½
Mean draught, feet	4¾
Displacement, about, tons	105
I.H.P., about	1,700
Speed, knots	22½

Armament.—Three single deck torpedo guns; three 1-pounder rapid firing guns; four automobile torpedoes, and 540 rounds 1-pounder ammunition; total weight, 6.4 tons.

If the average speed on trial equals or exceeds 22½ knots, the boat will be accepted; if below 22½ and over 21½ knots, a reduction, at the rate of $10,000 per knot below 22½ knots, will be made; if below 21½ knots, the boat will be rejected, or accepted at a reduced price mutually agreed upon.

Machinery designs for type 2, have been prepared by the Navy Department, which bidders may adopt if they choose. These designs provide for twin-screw triple-expansion engines of about 1,700 I.H.P., steam for which will be supplied by two water tube boilers.

ARGENTINE REPUBLIC.

San Martin.—This armored cruiser, built by the Messrs. Orlando Bros., Leghorn, for the Italian Government, and which, before purchase by the Argentine Government, was known as the *Varese*, was successfully launched on May 25 under her new name and nationality. She was named *San Martin* in honor of the liberator of Argentina, Chili and Peru. This vessel is a sister to the *José Garibaldi*, also purchased by the Argentine Government from Italy.

The length is 328.1 feet; beam, 59.7 feet; draught, about 23.25 feet; displacement at load draught, 6,732 tons. There is a 6-inch harveyized steel armor belt, and a central citadel with the same thickness of armor.* The protective deck varies in thickness from .87 to 1.46 inches.

The armament consists of two 9.84-inch guns, ten 5.9-inch, six 4.7-inch, ten 2.24-inch and ten 1.46-inch rapid fire guns, 4 smaller guns and five under-water torpedo tubes. There is one military mast with two tops.

The twin-screw engines, designed to develop 13,000 I.H.P. and give the vessel a speed of 20 knots, were built by the Hawthorn-Guppy Co. There are eight single-ended, four-furnace boilers, in four compartments, forward and abaft of the engines. The working pressure is 155 pounds per square inch. The propellers are four bladed.

José Garibaldi.—This twin-screw armored cruiser, built by Messrs. G. Ansaldo & Co., at Sestri Ponente, for the Italian Government, and launched on June 27, 1895, was sold by the builders to the Argentine Government. Messrs. Ansaldo agreed to build for the Italian Government a similar vessel, and to deliver it by the time originally agreed upon for the *Garibaldi*.

* The armor of the belt and citadel project beyond the hull of the vessel.

Belleville water tube boilers are to be installed in the new vessel instead of cylindrical boilers.

The dimensions and armament of the *José Garibaldi* are the same as for the *San Martin*, described above.

The engines were designed by Messrs. Maudslay Sons & Field, London, and built by Messrs. Ansaldo & Co. Quick work was done in constructing the machinery, it being ready for trial eleven weeks after the vessel had been launched.

There are two inverted, triple-expansion engines, with cylinders 42, 63 and 93 inches in diameter, the stroke being 47 inches. The following particulars of the engines and boilers are from "Engineering," London. Each cylinder is supported by four cast-steel columns, with cast-iron crosshead guides bolted on their faces and standing on cast-steel main bearing frames. The high pressure cylinders are fitted with piston valves, while the intermediate and low have double ported slide valves, all being worked by double eccentrics and Stephenson's link motion. The piston rods, connecting rods, and shafts are of steel, the crankshaft being made in three parts interchangeable. The condensers, two in number, are of delta metal, and are fitted with horizontal tubes through which the cooling water passes, and have a cooling surface of 14,600 square feet. There are two single-acting air pumps made of gun metal, 33 inches in diameter and 21 inches stroke, worked by beams from the low pressure crossheads. For the purpose of keeping a vacuum in the condensers, while the main engines are at rest, each of the circulating pumps, which are worked by independent compound engines, is fitted with a small auxiliary single-acting air pump. These pumps draw from the condensers and deliver into the feed tanks. The propellers are of gun-metal, each having four blades, the pitch being made adjustable from 21 feet to 25 feet.

Steam is supplied by eight single-ended cylindrical boilers, 15 feet $2\frac{1}{2}$ inches in diameter and 9 feet 11 inches long, working at a pressure of 155 pounds per square inch. Each boiler has four corrugated furnaces, 3 feet 6 inches in diameter and 7 feet 4 inches long, and two separate combustion chambers. The total grate surface is 775 and the heating surface, 21,500 square feet.

The tubes are 2½ inches in diameter, and are fitted with ferrules at the combustion chamber end. There are two funnels, 8 feet in diameter and 80 feet high.

The expected speed is 20 knots. The coal capacity is 600 tons. Provision for liquid fuel supply raises the total fuel capacity to about 1,000 tons. The boilers are arranged as in the *San Martin*.

Buenos Aires.—This cruiser, built by Messrs. Armstrong, Mitchell & Co., was described and an account of her trials given on page 806 of Vol. VII. The following particulars of the machinery, built by Messrs. Humphreys, Tennant & Co., Deptford, is now available, and is taken from "Engineering," London:

The twin-screw engines are of the four-cylinder, vertical, inverted, triple-expansion type, with cylinders 40, 60 and 66 (2) inches in diameter, the stroke being 36 inches. The cylinders are supported on cast-steel standards at the back, which carry the guides, and there are wrought-steel columns in front. The cylinders are steam jacketed with steam of boiler pressure for the high pressure cylinders, the jacket steam being reduced in pressure by reducing valves for the other cylinders. They have iron liners, the sides and bottoms of the cylinders both being jacketed. The link motion is of the ordinary type, with adjusting gear for linking up the low pressure cylinders independently. The pistons are of the ordinary dished shape, and are of cast steel. They have single packing rings of cast iron, with spring at the back. All the valves are of the flat type, with relief rings at the back, and balance pistons to take the weight of the valves. The piston rods are solid with the crosshead, and are of forged steel. The shoe plates are fitted with white metal, both for ahead and astern sides, and also with water service. The connecting rods are of forged steel, the top end brasses being of gun metal, while the big ends are of gun metal lined with white metal. The crankshaft is hollow and of steel, each pair of cylinders having a two-throw crankshaft in one solid forging. The proportions of the after crankshaft differ from those of the forward shaft, since each low pressure cylinder develops only about half the power of the high pressure, or the intermediate pressure cylin-

der. The eccentric straps have gun metal liners with white metal inside. The bottom frames are of cast steel, and consist of eight cross girders bolted to steel castings which are riveted to the ship's structure. Each cross girder carries one main bearing; the latter being of gun metal lined with white metal. These bearings vary in length according to the duty required of them, and are held in place by wrought-steel caps and bolts.

The condensers are four in number, two to each set of engines, and are of gun metal, the steam passing through the tubes. They are placed at the back and front of the engine. The condensing surface is 16,300 square feet for the four main condensers. The tubes are $\frac{5}{8}$ inch, and are secured in the tubeplates by screw glands and tape packing. The air pumps are worked direct from the after low pressure pistons of each set of engines, stuffing boxes being, of course, provided. They are single-acting, and have ordinary rubber valves for foot, bucket and delivery valves. The condensing water is circulated by centrifugal pumps in the ordinary way. These are placed at the after end of the engine room, there being a pump to each pair of condensers, the service being interchangeable at will for either engine.

Reversing is effected by a double-cylinder engine placed on the standard of the intermediate cylinder. There is the usual handwheel gear. The lubricating arrangements are very complete. The thrust block is of cast iron lined with white metal.

The propellers are of gun metal, three-bladed, and 13 feet 9 inches in diameter by 18 feet 3 inches pitch.

The boilers are eight in number, four single and four double-ended. They have iron tubes, and are fitted with Humphrys' patent screwed connection of protecting cap at the combustion chamber end. The double-ended boilers are 14 feet 2 inches in diameter by 18 feet 2 inches long. They have six furnaces, 3 feet 8 inches in diameter. The single-ended boilers are 14 feet in diameter and 9 feet $3\frac{1}{2}$ inches long, and have each three furnaces, 3 feet 8 inches in diameter. There are six feed pumps of the Worthington type.

The estimated power of the engines was 17,000 indicated

horse power for forced draft. It will be remembered that the ship made a speed of 23.202 knots on a six hours' run, the air pressure being $\frac{4}{10}$ inch, the indicated horse power being 14,000. The steam pressure was 155 pounds. The natural draft trial being so satisfactory, and the speed so easily attained, a forced draft trial was not required by the purchasers.

Santa Fé.—The first of the four partially-armored destroyers, mentioned on page 161 of the February number, was launched at Messrs. Yarrow & Co., Poplar, on May 16, and completed her official trial on July 9. The following is from "Engineering," London:

The vessel is 190 feet 8 inches long over all, has a beam of 19.5 feet and a depth amidships of 12 feet, the displacement on a draught of 5 feet being about 250 tons. The hull is of mild steel and is protected, at the ends and on the sides of the machinery space, by $\frac{1}{2}$-inch plates.

The armament consists of one 14-pounder and three 6-pounder rapid fire guns, two Maxim machine guns and three 18-inch torpedo tubes, one of these in the bow. The engines are twin-screw, triple-expansion, and have cylinders 18, 26 and 39.5 inches in diameter, the stroke being 18 inches. There are six Yarrow boilers, capable collectively of supplying steam for 4,000 indicated horse power. The weight of each of these boilers is $6\frac{3}{4}$ tons with water and fittings. The propellers are of manganese bronze, each with three blades, 7 feet in diameter, and have a pitch of 8 feet. The contract speed was 26 knots.

For feeding the boilers the new system adopted by this firm has been fitted (described under Notes). There is in the engine room a main feed pump, which takes water from the hot well and pumps it into a large cylindrical vessel at a pressure of 30 pounds to the square inch. Across this vessel are stretched diaphragms of flannel, through which all the water going to the boilers has to pass in order to abstract grease. Leading from this vessel is a single feed main, which runs the length of the boiler compartments. To each of the six boilers there is a separate feed pump which has its suction from the feed main. The steam pipe to the separate feed pump is taken from its boiler at a point about the

normal water level, there being, however, an internal swiveling pipe by which the level can be altered if necessary. If the boiler become too full, water, in place of steam, flows into the steam pipe. The pump steam cylinder thus becomes choked, and the action of the pump is all but stopped. When the water level falls again, through evaporation taking place in the boiler, steam once more passes to the pumping engine, which thus recommences its proper functions. The exhaust from the pumps is not taken to the condenser, but into the feed main.

On each destroyer there are eight feed pumps of the Henry R. Worthington type, with steam cylinders 5.25 inches in diameter, water cylinders 3½ inches in diameter, and a stroke of 6 inches.

The official trial was of three hours' duration, the vessel carrying a load of 35 tons. The mean results for the three hours were as follows: Steam pressure, 149 pounds per square inch; steam pressure in first receiver, 62, and in second receiver, 10 pounds per square inch; vacuum, 25 inches; revolutions per minute, 354.6; air pressure, 1¼ inches; speed, 26.525 knots. The contract I.H.P. of 4,000 was not reached. The slip of propellers was 5.25 per cent., the mean draught being 4 feet 5½ inches.

The mean speed for the six runs over the mile was 26.7 knots.

AUSTRIA.

Budapest.—This coast defense vessel, some data of which were given on page 811 of Vol. VII, was successfully launched at Trieste on April 27.

The following particulars of this vessel, and the sister vessels, *Wien* and *Monarch*, are in addition to those given on page 417 of Vol. VII. These vessels differ only in their boiler installations, the *Budapest* having Belleville, and the others, cylindrical boilers.

The turrets will be turned, the turret guns trained, and the ammunition hoisted by electric motors.

There are two broadside torpedo tubes.

The engines are to make 140 revolutions at full power, 8,380 I.H.P. The propellers are three-bladed, with a diameter of 14.5 feet, and a mean pitch of 14.23 feet.

The *Budapest* has 16 Belleville boilers in two fire rooms. The working pressure will be 155 pounds, and the maximum allowable pressure in boilers, 250 pounds per square inch.

BRAZIL.

Caramuru.—The first one of the three torpedo gunboats building by the Germania Co., Kiel, Germany, was launched April 1. The length is 259.1 feet; beam, 30.84 feet; draught of water, 10.17 feet; displacement, 1,014 tons.

The armament will consist of two 4.13-inch, six 2.24-inch and four 1.46-inch rapid fire guns; and three 17.72-inch torpedo tubes, one in the bow and two on deck.

There are two triple-expansion engines, which, under forced draft, are guaranteed to develop 5,918 I.H.P., and to give the vessel a speed of 23 knots.

CHILI.

Almirante Simpson.—This torpedo gunboat, described on page 386 of the May number, completed satisfactory official trials on July 23.

The mean speed for the six runs over the measured mile at Skelmorlie was 21.5 knots, and for the three hours' run, 21.25 knots, or, one-fourth of a knot over the contract speed.

On the six hours' natural draft trial, with $\frac{1}{2}$-inch air pressure, the mean speed was 17.75 knots, and the coal consumption "very light."

Guardia Marina Riquelme and **Teniente Serrano.**—The third and fourth of the thirty-knot destroyers built by Messrs. Laird Bros., Birkenhead, were launched on June 13 and May 16, respectively.

Torpedo Boats.—Six first-class boats are building by Messrs. Yarrow & Co. They will be 152.5 feet long and have a beam of 15.25 feet. The guaranteed speed with full load is 25.5 knots. The I.H.P. of the triple-expansion engines will be about 2,000. The bunker capacity will be 40 tons. The armament will consist of the usual rapid fire guns and torpedo tubes. These vessels will be an improvement on the Austrian torpedo boat *Viper*, built by Messrs. Yarrow & Co., and described on page 384 of the May number.

CHINA.

Three Cruisers.—These vessels are building at Stettin, Germany, by the Vulcan Works. The length is 328 feet; beam, 41 feet; draught, 27 feet 7 inches; displacement, 2,903 tons; I.H.P., 7,397; speed, 19.5 knots. The armament will consist of three 5.9-inch, eight 4.13-inch, six 1.46-inch rapid fire guns; six Maxim machine guns, and three torpedo tubes.

DENMARK.

Skjold.—This coast defense vessel, built at the dockyard, Copenhagen, was launched on May 9. Her length is 221 feet; beam, 37 feet; displacement, 2,122 tons; I.H.P., 2,170; speed, 13 knots.

The hull is of steel, and is divided into 51 compartments besides the double bottom compartments. The armor belt is of harveyized steel, 8.86 inches thick in the middle and tapering to about 7 inches at the ends. It extends from 3.5 feet below to 3 feet above the water line. The protective deck is about 2 inches thick.

The armament will consist of one 9.45-inch gun in a turret, protected by 7.87-inch armor; three 4.7-inch rapid fire guns in turrets, protected by 4.33-inch armor; four 1.85-inch rapid fire guns and one machine gun. The turrets will be worked and the ammunition hoisted by electric motors.

Hajen.—This torpedo boat, the third one built at the government yard at Copenhagen, has recently been completed. The displacement is 143 tons and the I.H.P., 2,200. She will have torpedo tubes and two rapid fire guns.

ENGLAND.

Canopus and class.—Of these five battleships, authorized this year, and of which general data were given on page 378 of the May number, one is to be built at the Chatham dockyard and will be known as *Battleship No. 2.* The plans for the second vessel have been received at the Devonport dockyard and work commenced. It has not yet been announced which vessel is to be named *Canopus.*

Hannibal.—This first class battleship of the *Majestic* type, was

successfully launched at the Pembroke dockyard on Tuesday, April 28. The launching weight of the vessel was 7,550 tons, and of the cradle and sliding ways, 400 tons, making a total weight on the ways of 7,950 tons. The estimated cost of the vessel is $4,687,515. She was laid down on May 1, 1894.

The machinery was built by Messrs. Harland & Wolff, Belfast, Ireland.

The *Hannibal* will be fitted with three dynamos, each of 400 ampères and 80 volts. The installation will require about 900 incandescent lamps, and three search lights, each of the latter being of 30,000 candle power.

Terrible.—Satisfactory preliminary trials of this first class protected cruiser were made on the Firth of Clyde on June 22. This cruiser was fully described on page 584, Vol. VI. During the trials, a speed of 20.5 knots was obtained with the engines running at 100 revolutions per minute, and 21.5 knots, with 105 revolutions. The highest I.H.P. obtained was 22,000.

On the trip down from the contractor's yard to the Portsmouth dockyard, where the vessel is to be finished, only 24 of the 48 Belleville boilers were used. During nearly the whole trip, 70 revolutions per minute were kept up, the speed being 15 knots. She had on board about 500 tons of coal. Her draught was 20 feet 4 inches forward and 26 feet 4 inches aft. Her normal load draught will be 27 feet.

The *Terrible* was sheathed, and her under water torpedo tubes put in at Portsmouth, and will soon be ready for her trials. It is proposed to run for 30 hours with 5,000 I.H.P., then, if nothing prevents, 30 hours with 18,000 I.H.P., and finally make an 8 hours' full power trial.

Powerful.—This cruiser, which was fully described on page 599 of Vol. VII, made preliminary contractor's trials in July. On Monday, July 13, she left Barrow, and the next day, at Liverpool, she brought up her coal supply to 1,200 tons, and took on board fresh water. On Wednesday she had an unofficial trial of her machinery, slowly working up to 95 revolutions, at which, in a run of six hours, she maintained a mean speed of 19 knots, with all her forty-eight boilers in use.

The ship left Liverpool at 8·30 on Wednesday evening, using at first only sixteen boilers, and, with 60 revolutions, she attained a speed of 12 or 13 knots; but on Thursday morning, eight more boilers were lighted up, and the revolutions increased to 75, when the speed slightly exceeded 15 knots.

The vessel arrived at the Portsmouth dockyard on July 17, the speed having been reduced to 5 knots to catch the tide going in. The machinery worked smoothly, and gave no trouble of any kind.—(" Engineering," London.)

Blake.—This armored cruiser, the trials of which, after refit, were given on page 168 of the February number, recently arrived at Portsmouth and reported a fatal accident on board. On June 24, while on the way to Portland, and nearing Land's End, a full speed trial was commenced. Soon afterwards an explosion occurred in No. 3 fire room, its force being so great that it was felt in every part of the ship. Five of the six firemen in the compartment were seriously injured, and another man was so severely scalded that he died soon after being taken out of the fire room. An examination, made on June 27 by Mr. T. J. Davey, engineer surveyor for the coroner, showed that the top of the combustion chamber was down about 3 inches for about 5 feet in way of the two after lower fires, and that ten stays, $1\frac{1}{4}$-inches in diameter and pitched 7 inches, had pulled through the nuts in way of damage; the whole length of the top of combustion chamber was down more or less, but the stays were good. The gauge glass and pressure gauge connections were found in good order. The internal surfaces of the damaged boiler were found to be generally clean, there being no scale or grease. No flaw was found in the top plate, but it was discolored and had every appearance of having been overheated. Mr. Davey's opinion was that the explosion was caused by overheating of the plate and stays through want of attention in regulating the feed water.

The damaged boiler, No. 3, starboard forward, is double-ended, 15 feet in diameter and 18 feet long, with eight furnaces, and has one common combustion chamber, 13 feet by 3.5 feet, with cross brick walls.

The evidence given at the inquest by Messrs. George E. A.

Crichton and J. Thomson, engineer officers of the *Blake*, and by the water tender stationed in that fire room, was opposed to the opinion of the surveyor expert that the cause of the explosion was due to low water. All of these witnesses testified that there were from 3 to 4 inches of water in the glass. Mr. Thomson had himself tried the gauge glass only a minute or two before the accident.

The "Times" says that the coroner's jury handed in a verdict on July 27. They found that "the accident was caused by culpable negligence through failure to secure a sufficiency of water in the boilers, and that the officers, whose duty it was to see that the water supply was sufficient, were guilty of that negligence." Two engineer officers, who inspected the damaged boiler on behalf of the Admiralty, practically concurred in the report and finding of the civilian expert. They also found that two of the gauge glasses were partly choked at the bottoms by the rubber packing. The feeding apparatus was found in a satisfactory condition.

Inspection at the Devonport dockyard showed that two other boilers in No. 3 fire room were injured.

Eclipse.—This second class cruiser, the hull and machinery of which were built at the Portsmouth dockyard, has completed satisfactory natural and forced draft trials. Some particulars of this vessel were given on page 604, Vol. VI. She was launched on July 19, 1894. The principal data are here repeated. Length, 350 feet; beam, 53.5 feet; draught, mean, 20.5 feet; displacement, 5,600 tons; coal carried on this displacement, 1,000 tons; I.H.P., natural draft, 8,000, forced draft, 9,600; speed, 19.5 knots.

The twin-screw, triple-expansion engines have cylinders 33, 49 and 74 inches in diameter, the stroke being 39 inches. There are eight single-ended boilers, each 14.5 feet in diameter and 9 feet 11½ inches long. Each of the twenty-four corrugated furnaces is 3.75 feet in diameter. The total grate surface is 630 square feet.

On June 22, the eight hours' natural draft trial was made. The draught at the start is given as 18 feet 8 inches forward and 22 feet 4 inches aft, or a mean of 20.5 feet. The average results are as

follows: Steam in boilers, 152.7 pounds per square inch; vacuum, 25.7 inches starboard and 26.5 inches port; revolutions per minute, starboard, 133.7, port, 135.7; I.H.P., 8,220, or 220 above the designed power; speed, 19.2 knots by patent log. An air pressure of .39 inch was used. Coal per I.H.P. per hour, 2.27 pounds. The engines worked smoothly, the average temperature in the engine room being 85 degrees. Experiments were made during the trial with the homacoustic voice pipe, which has been improved since it was placed in the *Fox*, and gave very satisfactory results, no difficulty being experienced in communicating between the fore bridge and the engine room.

On June 24, the four hours' forced draft trial was made, the draught being 18 feet 4 inches forward and 22 feet 1 inch aft, or a mean of 20 feet 2½ inches.

Steam pressure, 155 pounds per square inch; vacuum, starboard, 25.7, port, 26.6; revolutions per minute, starboard, 141.17, port, 142.36; I.H.P., starboard, 4,820, port, 5,033, total 9,853, or 253 over the estimated power; speed, 20.1 knots, by patent log; air pressure, .94 inch. The engine and fire rooms were so cool that the two ventilating fans were not used.

On June 27, the thirty hours' coal consumption trial was made. The draught was 18 feet 2 inches forward, 22 feet 2 inches aft, or a mean of 20 feet 2 inches.

Steam pressure, 135.6 pounds; vacuum 26.5, starboard and port; revolutions per minute, starboard, 115.7, port, 116.3; I.H.P., starboard, 2,418, port, 2,420, total, 4,838; speed, by patent log, 16.8 knots; no air pressure; coal per I.H.P. per hour, 1.83 pounds.

At the end of this trial, four torpedoes were fired from the stern tube with accuracy and success. At full speed this tube is liable to become submerged, and in some British vessels it has been found that the balance chamber collapsed and the discharge of the torpedo was prevented, owing to the submersion of and consequent entrance of water into that tube. On this vessel, no such effect was noticed.

Talbot.—This second class cruiser, a general description of which was given on page 516 of Vol. V, has completed her steam

trials. The *Talbot* was built at the Devonport dockyard, and is 350 feet long, with a beam of 53 feet and mean load draught of 20.5 feet, the displacement being 5,500 tons. The machinery, built at the same dockyard, was designed for 8,000 I.H.P. and 18.5 knots under natural draft, and 9,600 I.H.P. and 19.85 knots under forced draft.

On May 7, the natural draft trial of eight hours was successfully completed with the following results. Steam pressure, 142 pounds per square inch; vacuum, starboard, 25.6, port, 25 inches; revolutions per minute, starboard, 133, port, 131.1; I.H.P., starboard, 4,256, port, 4,206; I.H.P., total, 8,462; air pressure, in inches of water, 0.41; speed, 19.2 knots. Before the trial commenced, the vessel had been brought down to a mean draught of 20.5 feet, giving a displacement of 5,620 tons. Gun, torpedo and anchor trials were satisfactorily completed.

On May 13, the four hours' forced draft trial was made with the following results: Steam pressure, 144 pounds per square inch; vacuum, 25 inches; revolutions, starboard, 140.2, port, 138.9; I.H.P., starboard, 4,957, port, 4,819; I.H.P., total, 9,776; air pressure, in inches of water, 1.06; speed, 20 knots.

The thirty hours' coal consumption trial took place with the engines working at three-fifths of the natural draft power, this being the most economical rate at which vessels of this class can be steamed for any length of time. The average results of this trial were as follows: Vacuum, 26 starboard, 26.1 port; revolutions per minute, 114.9 starboard, 113.5 port; I.H.P., 2,451 starboard, 2,462 port; total I.H.P., 4,913; air pressure, *nil;* speed, 16.68 knots, and the coal consumption, 1.84 pounds per indicated horse-power per hour. The vessel's stowing capacity is 550 tons.

Arrogant.—This second class cruiser, partially described on pages 419 and 814 of Vol. VII, was launched at the Devonport dockyard on May 26. The other three vessels of this type, the *Gladiator*, *Furious* and *Vindictive*, all building at Government dockyards, have not yet been launched. The principal dimensions of the *Arrogant* are: Length, 320 feet; breadth, 57 feet 6 inches; mean load draught, 21 feet; displacement, 5,800 tons. Her keel was laid on June 10, 1895. The armament will consist

of rapid fire guns entirely, there being four 6-inch, six 4.7-inch, eight 12-pounders (12 cwt.), one 12-pounder (8 cwt.), and three 3-pounder guns, besides five Maxim machine guns. There are two 18-inch submerged torpedo tubes.

The twin-screw engines are of the usual vertical, inverted, triple-expansion type, and are to develop 10,000 I.H.P. under forced draft. The cylinders are 26, 42 and 68 inches in diameter, the stroke being 39 inches. The engines are in separate compartments. The connecting rods are 6.5 feet long between centers. The diameter of the piston rods is $7\frac{1}{4}$ inches. The crank shaft is $13\frac{3}{4}$ inches in diameter with a $7\frac{3}{4}$-inch axial hole. The condensers are cylindrical and placed outboard of the engines, each having a cooling surface of 5,280 square feet. The air pumps are 27.5 inches in diameter and have a stroke of 11 inches.

The eighteen Belleville boilers, some particulars of which were given on page 170 of the February number, under the sister ship *Vindictive*, have a grate surface which is variously given as 860 and 880 square feet. The heating surface is about 26,000 square feet. As the boilers are placed in three equal groups in separate compartments, there will be three smoke pipes.

The vessel is to be completed for sea by March, 1897, and her total cost is estimated at about $1,337,150. The complement of officers and men will be 419.

Isis.—This second class sheathed cruiser was launched on June 27, by the London and Glasgow Engineering and Iron Shipbuilding Co., at their Middleton yard, Govan. She is a sister vessel to the *Dido*, built by the same company, and described on page 388 of the May number.

Pactolus.—This third class cruiser, mentioned on page 391 of the May number of the JOURNAL, has been named, and will be built at Elswick.

Swordfish.—This 27-knot torpedo boat destroyer, built by Messrs. Armstrong, Mitchell & Co., Elswick, was delivered at the Chatham dockyard in June. All machinery was built by Messrs. G. E. Belliss & Co., Birmingham.

The following particulars of the vessel, her machinery, and

of the three hours' full power trial are from "Engineering," London:

The vessel is 200 feet long and has a beam of 19 feet. The twin-screw engines are of the four-cylinder, triple expansion type, with cylinders 18.75, 27.25 and (2) 28 inches in diameter, the stroke being 18 inches. The boilers are of the Yarrow type, but built by Messrs. Belliss & Co.

About June 12, the natural draft trial was commenced, but stopped after 2½ hours by the breaking down of the port engine. On June 30, the trial was again interrupted by defects in the P. L. P. slide valve. On July 9, a satisfactory three hours' full power trial was made with the following results:

Speed of vessel, knots	26.8	
Mean steam pressure in boilers, pounds per square inch	194	
air pressure in stokeholds, inches of water	2.7	
	Starboard.	*Port*
vacuum in condensers, inches	23.8	24.2
revolutions per minute	397.7	391.3
pressure in cylinders, high, pounds per square inch	67.8	63.7
intermediate, pounds per square inch	34.3	33.0
forward, low, pounds per square inch	18.8	19.0
after, low, pounds per square inch	18.6	18.7
I.H.P., high	676	626
intermediate	724	684
forward, low	418	412
after, low	413	406
Total I.H.P., each engine	2,231	2,128
both engines	4,359	

The contract I.H.P. was 4,000.

It will be noticed that the power developed was very high for the speed obtained. This is chiefly due to the time of tide and to the fact that the vessel was weighted with 15 tons of cast iron ballast, which had to be bolted to the bottom in order to meet the Admiralty requirements as to stability. The specified weight for the machinery was 110 tons, and this was not exceeded, although the horse power was considerably above the contract.

The official trial was necessarily made at high water, owing to the dockyard arrangements, and it is estimated that there was a

considerable loss in speed due to cross currents set up on the Maplin mile at the turn of the tide. On the day previously to the official trial the vessel was taken out for a preliminary run, when the I.H.P. was 4,500, and a speed of 27½ knots was reached on the mile. Throughout the trials the boilers, as well as the engines, worked with entire satisfaction.

The vessel has been accepted.

Skate.—This torpedo boat destroyer, which was recently overhauled, and many defects in hull and machinery corrected, at a cost of about $10,000, started on a three hours' trial of the repaired machinery and hull, on Wednesday, July 8. After an hour's steaming, on account of a loud thumping, accompanied by the peculiar jerking of one of the shafts, the engines were stopped. An examination showed that the outboard bracket of the starboard propeller shaft had broken and slipped off. The vessel returned to harbor, leaking badly on the way back. Later, the starboard shaft was found to be bent.

This vessel was commissioned as a reserve boat, to take the place of the first destroyer which might become disabled during the naval manœuvres.

The *Skate* was built by the Naval Construction and Armaments Co., has twin-screw engines, and four Blechynden water tube boilers. On the official trial she obtained a speed of 27.1 knots.

Salamander.—This torpedo gunboat, built in 1891, is to have water tube boilers in place of the present locomotive boilers. The cost of this change is estimated at over $100,000.

Hardy.—This torpedo boat destroyer, built by Messrs. Doxford & Sons, Sunderland, made her official full power trials on the Maplin measured mile on June 6. The contract speed was 26 knots. The average results for the three hours' run, were: steam pressure at boilers, 189 pounds per square inch, revolutions per minute, 360; I.H.P., 4,184; speed, 26.514 knots. The average speed over the measured mile, for six runs, was 26.8 knots.

In the beginning of July, the coal consumption trials were made, but were not successful, the average consumption for five hours being greater than the contract requirement. The con-

tractors are making some alterations in the furnaces with a view to obtaining satisfactory results.

Brazen and **Electra.**—The first two of the 30-knot destroyers building by Messrs. J. & G. Thomson, Clydebank, were launched on July 2 and 14, respectively. The displacement is 300 tons and the expected I.H.P., 5,800.

Hart.—On page 396 of the May number, under the trial data, the number of revolutions is given as 196.1. This is incorrect, no revolutions being published.

Desperate.—This torpedo boat destroyer, while running her trials on June 27, in charge of the contractors' men, met with a serious accident. She had been over the measured mile six times, and was steaming at the rate of 30 knots, with a steam pressure of 210 pounds in the boilers, when an explosion occurred and a large volume of steam escaped from the engine room. After steam was shut off, it was discovered that the starboard I.P. crosshead had broken, and the bottom cylinder head had been knocked out. Three men were badly scalded, but are reported as progressing favorably. The vessel returned to the yard of the contractors, Messrs. Thornycroft & Co.

Rocket.—The London "Times" says that this destroyer has broken down five times, and, although on her official trials she exceeded a speed of 27 knots, her boilers prime to a serious extent if she is now put to a speed of more than 14 knots. Before she was commissioned, her boilers were partly retubed, steel being substituted for the copper tubes.

After a short service with the Particular Service Squadron, the vessel has been detached from this duty, and all of the boiler tubes are to be replaced by steel tubes at the Keyham dockyard.

Zebra, Conflict, Teazer and **Wizard.**—The following particulars of the machinery of these torpedo boat destroyers are in addition to those given on page 181 of the February number.

The engines have cylinders 19.5, 28.75, 30.75 and 30.75 inches in diameter, the stroke being 18 inches. The cylinders are supported on turned steel columns standing on and firmly bolted to the cast steel crank bearing frames. All cylinders have piston

valves, worked by ordinary link motion with double eccentrics. The air pumps are single acting, of the plunger type, and are worked by overhung cranks at the forward ends of the main crank shafts. The surface condensers are of sheet brass, the water passing through the tubes, and have a total cooling surface of 3,380 square feet. The independent centrifugal circulating pump is 22 inches in diameter.

The three boilers in each vessel are each 13 feet 4 inches wide, 10 feet 9.5 inches long and 10.5 feet high, and have two furnaces, 5 feet by 7 feet long, giving a total grate surface, for the three boilers, of 210 square feet.

The *Wizard's* propellers will work inwards, all the others outwards.

Thirty-knot Torpedo Boat Destroyers.—Eighteen additional destroyers have been ordered and named as follows. For the other 30-knot destroyers, see page 401 of the May number and page 820, Volume VII.

Coquette, *Cygnet* and *Cynthia* to be built by Messrs. J. I. Thornycroft & Co.; the *Arab* and *Kestrel*, by Messrs. J. & G. Thomson, of Clydebank, Glasgow; the *Bullfinch* and *Dove*, by Earle's Shipbuilding and Engineering Company, of Hull; the *Cheerful* and *Mermaid*, by Messrs. Hawthorne, Leslie & Co., of Newcastle-on-Tyne; the *Fairy*, *Gipsy* and *Osprey* by the Fairfield Shipbuilding and Engineering Company, of Glasgow; the *Leopard* and *Otter*, by the Naval Construction and Armaments Company, of Barrow-in-Furness; the *Sylvia* and *Violet*, by Messrs. Doxford & Sons, of Sunderland; and the *Flirt* and *Fawn*, by Palmer's Shipbuilding Company, of Jarrow-on-Tyne.

Albatross and **Express.**—These destroyers were ordered in April. The *Albatross*, designed to make 32 knots, is building by Messrs. Thornycroft & Co., and will have their water tube boilers. The *Express*, designed for a speed of 33 knots, is building by Messrs. Laird Bros., Birkenhead, and will have Normand boilers. Among the offers to build boats of a speed of over 30 knots was one from Messrs. Hawthorne, Leslie & Co., Newcastle-on-Tyne, who were prepared to design a vessel to make 33.5 knots. On page 401, the name of the builders of the second

32-knot destroyer was given as Messrs. J. & G. Thomson, Clydebank. Recent reports show that this was wrong, and that the information given above for the *Express* should be substituted.

FRANCE.

Bouvet.—This first class triple-screw battleship, built by the Chantiers de Caudan at Lorient, France, was successfully launched on Monday, April 27.

The *Bouvet* is the largest battleship in the French Navy. The principal data, as given by the "Yacht," Paris, are as follows:

Length, feet	401.26
Beam, feet	70.21
Draught, feet	27.58
Displacement, tons	12,012
I.H.P., forced draft	13.808
Speed, knots	17.5

The hull is of steel and is subdivided into a very large number of compartments. The armor belt is 15.75 inches thick in the middle of the vessel and tapers to 7.87 inches at the bow and stern. The protective deck is 3.54 inches thick. There is a splinter deck below this on a level with the lower edge of the armor belt. The armor plates are of nickel and manganese steel.

The armament will consist of two 12-inch guns in closed turrets amidships, one forward and one aft; two 10.81-inch guns of the 1893 type, one on each broadside, in turrets. Eight 5.45-inch rapid fire guns in closed turrets, arranged as in the *Carnot*, (see page 401 of the May number of the JOURNAL;) eight 3.94-inch rapid fire guns on the superstructure, each protected by a shield, 2.83 inches thick. There will be, besides, twelve 1.85-inch and twenty 1.46-inch rapid fire guns distributed about the vessel and in the military tops. There will be four torpedo tubes, two of them under water.

There will be three vertical, triple-expansion engines driving three screws and designed for 13,808 I.H.P. The boilers will be of the Belleville water tube type. The coal supply will be about 800 tons, and the complement 630 officers and men.

Jaureguiberry.—This battleship, described on page 616 of Vol. VI, has completed her official trials. The results of the preliminary trials, made in the latter part of April, were given on page 403 of the May number.

On May 20, the natural draft trial was made with the following results: Revolutions per minute, about 96; I.H.P., about 13,630; mean speed, 17.6 knots; maximum speed, over 17.75 knots. As the contract speed under forced draft is 17.5 knots, this result was very gratifying to the builders, the Société des Forges et Chantiers de la Mediterranée. The coal consumption, which was limited by the contract to 2.01 pounds per I.H.P. per hour, was not quite 1.77 pounds. The combustion per square foot of grate surface was less than the 22.13 pounds allowed by the contract.

On May 22, satisfactory trials were made of the turret machinery and the gun carriages of the secondary battery.

On May 27, further trials were made on the measured mile. The mean I.H.P. was about 13,000, and the speed, 17.67 knots. The mean combustion per square foot of grate surface per hour was 31.46 pounds. Only 18 out of the 24 boilers were used.

As the speed attained under natural draft was greater than that required under forced draft, the two hours' full power trial was waived by the Minister of Marine.

On June 9, the vessel started on a 24 hours' coal consumption trial. For nineteen hours everything had been working very satisfactorily. During the twentieth hour, an explosion occurred in the port forward boiler of the port middle fire room, seriously scalding and burning the nine men in that compartment. Six men died soon after and the other three were in a precarious condition, but they will probably recover.

The furnace door of this boiler was open at the time, for the purpose of cleaning the fire, and the rush of steam and flame into the fire room was so sudden that the men were overcome almost instantly.

The details of the boilers were given on page 616 of Vol. VI, so that it will be sufficient to repeat that there are 24 Lagrafel-D'Allest water tube boilers, all with welded iron tubes, 3.15

inches in outside diameter. The boilers are arranged in groups of two, two groups being in each of the six fire rooms. The compartments are, therefore, rather small.

After the accident, a careful examination showed that one tube had burst. In a letter to London "Engineering," the director of the company says that this tube "opened at the weld for a length of 250 millimeters. The explosion of this tube resulted in its bending, and thus brought it into contact with the neighboring tubes, which slightly yielded to the thrust. Furthermore, the upper portion of the boiler becoming empty without the fires being put out, some of the tubes in the upper rows became overheated, and also bent; but none of these tubes, nor, in fact, any of the other tubes in the boiler (not even the one which exploded), were drawn from the tube plates or sustained any other injury. There was no shortness of water, and no blame can be attached to any men in charge of the boiler."

At the time of the accident, the steam pressure was between 155 and 170 pounds per square inch. The damaged boiler was one of the eighteen used on the trial of May 27, under a pressure of about 213 pounds per square inch.

It is worthy of note that the remaining fire room force went out, on the day after the accident, on the trial of the *Carnot*, fitted with the same type of boilers.

Amiral Tréhouart.—This battleship, the preliminary trial of which was noted on page 403 of the May number, completed a twenty-four hours' trial about the middle of May with highly satisfactory results. The average speed was a little over 14 knots, the revolutions, about 100 per minute, and the I.H.P., about 4,932. The coal consumption was 1.64 pounds per I.H.P. per hour.

Carnot.—This battleship, fully described in the May number, page 401, completed a satisfactory preliminary trial at 90 revolutions on June 11. The trial was to last three hours, but heating of one of the main journals at the end of 2¼ hours, caused a slight reduction in the speed. The I.H.P. developed was about 7,900 and the speed, 16 knots. A strong wind blew during the trial.

Another preliminary trial was made on June 23, the revolutions being 102, and the speed on the mile, 17.45 knots.

D'Entrecasteux.—This sheathed cruiser, described on page 751 of Volume V, was launched on June 12. She was built by the Forges et Chantiers de la Mediterranée at La Seyne, and was laid down in June, 1893. Her principal particulars are now given as follows: length on water line, 393 feet 8 inches; beam, 58.5 feet; draught, 25.75 feet; displacement, 7,986 tons; I.H.P., 13,500; speed, 19 knots.

The weight at time of launching was about 3,340 tons. The complement will be 21 officers and 500 men.

Cassard.—This cruiser, a sister vessel to the *DuChayla*, described on page 188 of the February number, was successfully launched at the Cherbourg dockyard on May 27. The machinery was built by the Creusot works, and was almost completely installed at the time of launching. This vessel was laid down on October 22, 1895, and is to be completed by November, 1897.

Descartes.—This sheathed second class cruiser, the principal data of which were given on page 805 of Vol. VI, started on a twenty-four-hours' trial on June 18. After running satisfactorily for about 8 hours, making 120 revolutions and attaining a speed of 18 knots, the trial was interrupted by leakage of some of the tubes of the Belleville boilers.

Early in July, a four hours' full power trial was made, a speed of over 21 knots being attained. The revolutions per minute were 136, and the coal per I.H.P. per hour, 1.84 pounds. Commenting on this trial and on the vessel, the "Yacht," Paris, says:

"This is a gain of two knots over the contract speed. It is to be regretted that a cruiser, so speedy and so powerfully armed, has, otherwise, certain defects which will necessitate modifications."

This cruiser was begun in the latter part of 1892, on the plans of the builders, the Société des Ateliers et Chantiers de la Loire at Nantes. Among the few changes made during her construction, two light signal masts were put in place of the designed military masts. The vessel was launched on September 27, 1895.

Fleurus.—The new boilers, referred to as necessary after the

collapse mentioned on page 173 of Vol. VII, have been put in. A part of the vessel's hull, below the protective deck, was removed, in order to put in the new boilers without cutting the protective deck.

Galilée.—The following data are additional to those given on page 405 of the May number.

The total cost of the vessel will be about $1,040,000. There are two above-water torpedo tubes. The protective deck is 1.5 inches thick. The boilers will be of the Belleville water tube type. The complement will be 11 officers and 287 men.

GERMANY.

Kaiser Friedrich III.—This triple-screw battleship, described on page 827 of Vol. VII, as the vessel to replace the *Preussen*, was successfully launched on July 1.

Kaiserin Augusta.—This triple-screw cruiser, the first one in the German Navy, made some very interesting screw, steering and power trials from September to December, 1895. The results of these trials have just been published and are taken from the "Marine Rundschau," Berlin. A description of this vessel and her official trials were given on pages 126, 289 and 846 of Vol. IV, of the JOURNAL.

The displacements and corresponding draughts for various loads were found by trials, as follows: With complete equipment in all departments, and 123 tons of fresh water in the double bottom, 6,192 tons; draught, forward, 21.26 feet, aft, 24.27 feet, mean, 22.76 feet. With complete equipment, but only half coal supply (about 420 tons), and about 59 tons of water in double bottom, 5,817 tons; draught forward, 19.68 feet, aft, 23.95 feet, mean, 21.81 feet. With complete equipment, but only 196 tons of coal, and about 39 tons of water in double bottom, 5,610 tons; draught, forward, 18.53 feet, aft, 24.01 feet, mean, 21.26 feet.

The turning power of the vessel is very good. A straight course can easily be steered at all speeds, a helm angle of one degree being sufficient in smooth water. The uncoupling of the middle screw exercises only a very slight influence on the

steering. With one side and the middle engine in operation, a helm angle of about 2° is usually necessary to steer a straight course; with only one side engine in operation, about 6°; in either case, very little motion of the wheel is required. For instance, on the full power trials with one side engine, a beam wind blowing with a force of 3, and the rudder being put over 6°, the wheel was hardly moved while running over the measured mile.

The vessel answers her helm quickly, motion beginning, on the average, about five seconds after the rudder has been set.

In turning half circles with the rudder hard over (39°), and running at 12 and at 18 knots, various combinations of the screws being tried, it was found that the time to circle to starboard was always shorter than that for the circles to port. It must be noticed that the starboard propeller is right handed, and the port and middle propellers, left handed.

The good effects of the middle screw on the steering capabilities of the vessel are shown by a comparison of the turning diameters. At a speed of 12 knots, running with all three engines, with the two side engines, and with the middle engine only, the respective diameters were 2,395, 2,778 and 2,181 feet.

To turn 16 points in the *shortest time*, regardless of the turning diameter, all three engines should go ahead. To turn in the *smallest circle*, regardless of the time, the outer and middle engines should go ahead and the inner engine back at about the same speed. Under the latter conditions, the turning diameter will be 2,034 feet at a speed of 12 knots, and 2,165 feet at 18 knots.

The manœuvring qualities of the vessel are very good, considering her length. If, when steaming at a speed of 18 knots, the engines are reversed to "full power astern," the vessel will stop in $1\frac{1}{2}$ minutes, and in a distance of about 1,310 feet; at 11 knots' speed, she will stop in 55 seconds and a distance of about 490 feet.

The heel of the vessel, fully equipped and turning at full speed with the rudder hard over, is seldom more than two degrees; at mean speed, it is about one degree.

At full speed, helm angles of 10 and 20° reduce the speed about

one and two knots, respectively; at mean speed, the reduction is less.

In spite of the strong demands made on the machinery during these trials, nothing happened to impair their efficiency or stop their working. No vibrations of the engines were noticeable until the revolutions reached 127 or 128 per minute. The vibrations were especially noticeable when the vessel carried only 196 tons of coal and when the engines were forced. The greatest and most uncomfortable vertical vibrations of the vessel took place when the revolutions were from 95 to 105 per minute. At higher revolutions, the vibrations of the vessel decrease on the upper deck, and are hardly noticeable between decks amidships; in the cabin and wardroom, writing is impossible and reading very difficult at over 110 revolutions.

The lowest number of revolutions at which the engines can be run continuously is 18 for the side engines and 22 for the middle engine; in smooth water, this will give a speed of 3 knots.

The lowest number of revolutions obtained on the trials, with all three engines still running, was 16 per minute, the I.H.P. being 138.67.

The maximum power ever developed with all three engines was obtained on a six hours' forced draft trial in the previous July, when the I.H.P. of main engines was 14,945.42 and of the auxiliaries, 494.14, or a total of 15,439.56.

A trial was also made with the middle engine running free, the propeller being uncoupled. It was found that at 77 revolutions per minute, the I.H.P. was 156.62, and at 119 revolutions, 226.75.

With jet condensation, the initial pressure in the H.P. cylinder being 72.7 pounds per square inch, the I.H.P. was 1,903.5 and the revolutions per minute, 66.7. The corresponding speed would be about 11.75 knots.

The maximum power obtained in the previous July could not be reached during these trials, although the boilers furnished sufficient steam of the necessary pressure. As no other cause could be found, this was ascribed to the want of water under the vessel, the depth averaging (during trial No. 2) about 52.5 feet.

No. of trial.	Kind of trials. (Measured mile.)	Total I.H.P.	Revolutions per minute. Mean of S. and P. engines.	Revolutions per minute. Middle engine.	Speed, knots.	Draught, mean, feet.	Displacement, tons.	Coal per I.H.P., main engines, per hour, pounds.	Coal used for auxiliaries. Per hour, pounds.	Coal used for auxiliaries. On radius of action, tons.	Radius of action with 846 tons coal. Naut. miles.
1	Maximum with 3 engines	13,425	125.8	127.1	21.589	21.10	5,631	...	...	...	...
2	Six hours' forced draft, 3 engines, 1.18-inch air pressure	13,898	126.4	127.8	21.508	21.81	5,897	2.063	244.71	...	...
3	Six hours' forced draft, 3 engines, 1.18-inch air pressure	12,561	123.0	123.3	21.022	22.63	6,212				
4	Three hours' forced draft, 3 engines, .47-inch air pressure	11,270	119.1	119.1	20.478	22.65	6,218	1.882	771.61	...	...
5	Twenty-four hours, $\frac{2}{3}$ full power, with .47-inch air pressure = greatest endurance performance, with 3 engines	7,072	102.0	102.0	17.751	22.42	6,131	...	771.61	...	...
6	Twenty-four hours, $\frac{2}{3}$ full power, with .47-inch air pressure = greatest endurance performance, with 3 engines	6,875	101.6	102.0	17.669	21.81	5,899	1.746	...	51.2	2,622
7	Same as 5, with 2 engines	7,098	109.8	71*	17.588	22 52	6,168	...	771.61	...	...
8	Same as 5, with 2 engines	6,874	109.3	71*	17.541	21.81	5,899	1.790	...	50.2	2,543
9	Twenty-four hours, 3 engines, 3—4,000 I.H.P.	4,448	86.75	86.5	15.196	22.52	6,168	...	725.31	...	...
10	Twenty-four hours, 3 engines, 3—4,000 I.H.P.	4,179	85.97	86.45	15.167	21.81	5,899	1.880	...	71.8	3,350
11	Twenty-four hours, $\frac{1}{3}$ full power, with .47-inch air pressure = service speed, with side screws	2,602	78.55	50.5*	12 792	22.52	6,168	...	672.40	...	...
12	Twenty-four hours, $\frac{1}{3}$ full power, with .47-inch air pressure = service speed, with side screws	2,340	76.25	49*	12.506	21.81	5,899	2.023	...	123.0	4,277
13	Same as 11, with middle engine	2,334	51*	91.1	11.688	22.50	6,162	...	806.9	...	...
14	Same as 11, with middle engine	2,305	51.5*	90.5	11.663	21.81	5,899	1.927	...	128.9	4,222
15	Two engines, middle screw uncoupled	8,766	116.6	74*	18.677	22.52	6,168	...	...	...	...
16	Two engines, middle screw removed	8,822	117.8	†	19.321	22 32	6,090	...	...	...	...
17	Middle engine, side screws uncoupled	3,898	61*	109.0	14.135	22.41	6,128	...	...	...	...
18	Middle engine, side screws removed	3,948	†	111.4	15.252	22.41	6,128	...	...	...	...

* Uncoupled. † Removed.

The regular speed which can be maintained under natural draft, using the fans for ventilating purposes only, is 18 knots.

The curves of I.H.P. for two and for three engines coincide very nearly between 5 and 17 knots. The coal consumption curves show that when steaming with two engines, from 450–650 pounds of coal per hour more are consumed than with all three engines. This gain is about offset by the increase in the running expenses, so that for any speed between 5 and 17 knots, and for the same running expenses, it is immaterial whether two or three engines are used. The curves of endurance or steaming radius show a difference of only 80 nautical miles, therefore, no greater distance can be steamed with two than with three engines, the advantages being limited to a reduced cost of oil, &c., easier work for the engineer force, and less liability of breakdowns.

Approximately the same thing may be said in regard to the use of one engine, as compared with two and three engines, but sufficient data are not available to make a definite statement.

The diameter of the side propellers is 14.76 feet, and of the middle one, 13.78 feet. During the first fourteen trials, the pitch of the side propellers was set at 20.01 feet, and that of the middle one at 19.02 feet; during the last four trials, the pitch was set at 20.34 and 19.35 feet, respectively.

The radius of action given in the table cannot be taken as the real radius, for the coal consumption during service runs would be about 15 per cent. greater than that on trial trips, on account of the fouling of boilers, the changing of boilers, the production of feed water, leaks and other causes. The real radius which can be depended on in practice will, therefore, be 15 per cent. smaller than that given in the table.

Cruisers M and **N.**—The second class triple-screw cruiser *N*, a sister vessel to cruiser *K*, described on page 828 of Vol. VII, has been ordered from the Vulcan Co., Stettin, and is to be completed in two and a half years. Another vessel, triple-screw cruiser *M*, is building at the dockyard at Danzig. Both will have water tube boilers.

Geier.—Some particulars of this sheathed third class cruiser and of her trials, were given on page 808, Vol. VI, and on page

192 of the February number. The following complete information, from the "Marine Rundschau," Berlin, and other sources, is now available.

This cruiser was laid down at the dockyard, Wilhelmshaven, on November 2, 1893; launched October 18, 1894, and finished October, 1895. The trials began on October 24, 1895, and, after their successful completion, the vessel was put out of commission at Kiel, on January 21, 1896.

The vessel has a length of 249.3 feet; beam, 34.78 feet; mean designed draught, 14.5 feet; displacement at this draught, 1,585 tons. Mean draught, fully equipped, 15.49 feet; with half coal supply, about 159 tons, the mean draught is 14.7 feet. The displacements corresponding to these draughts are 1,748 and 1,601 tons, respectively.

The armament consists of eight 4.13-inch guns, five 1.46-inch rapid fire guns, two machine guns and two 17.72-inch above-water torpedo tubes in broadside.

Aluminum was tried in the furniture and fittings of one of the officers' state rooms, but did not give satisfaction, the metal not possessing sufficient rigidity. It was also tried in some of the ports, ventilators and window sashes, but no definite verdict could be given, although it was shown that aluminum could be used only where it could always be well covered with paint, and where it was not exposed to bending forces.

The triple-expansion engines are in separate compartments, the cylinders being 16.4, 27.56 and 43.31 inches in diameter, and the stroke, 24.6 inches.

There are four three-furnace boilers, each 9.32 feet in diameter and 16.71 feet long. The total grate surface is 226 and the heating surface, 7,040 square feet.

The practical test carried out by the Trial Board showed that 317 tons of coal could be stowed. From the trial data, the radius of action at 15 knots is found to be 3,035, and at 10.5 knots, 5,017 nautical miles, the coal consumption at the former speed having been fixed at 3,509 pounds, and at the latter, at 1,485 (?) pounds per hour.

The following are the results of the trials:

Duration of trial, hours	6	3	24	24
Kind of trial	Forced, accept-ance.	Full power.	Con-sumption	Fixed speed.
Draught, forward, feet	14.04	14.27	13.91	14.2
aft, feet	16.73	16.40	16.53	16.6
Displacement, tons	1,731	1.723	1,703	1,732
Area midship section, square feet	402.7	401.3	397.	403.2
Speed, knots	16.29	16.29	14.97	10.471
Pitch of propellers, feet	14.76	14.76	14.76	14.76
Steam pressure in boilers, lbs. per sq. in	175	176	173.5	172
Revolutions per minute	139.1	137.6	121.3	83 9
I.H.P., starboard	1,405	1,445	912	293
port	1.439	1,475	916	307
total	2,844	2,920	1,828	600
Number of boilers in use	4	4	4	2
Air pressure, inches of water	.26	.28	...	...
Coal consumption, total, per hour, lbs	6,005	6,606	3,509	1,518
per square foot of grate surface per hour, lbs	26.57	29.23	15.53	13.43
per I.H.P. of main engines, air and circulating pumps, lbs. per hr.	2.02	2.18	1.8	2.2

Adding to the coal consumption as found on trial, an allowance of 15 per cent. for starting fires, distilling, feed water, decrease in efficiency of boilers after long periods of steaming, etc., the practical radii of action at 15 and 10.5 knots become 2,637 and 4,362 nautical miles respectively.

Cruiser G.—This cruiser of the fourth class is to be built by contract.

ITALY.

Marco Polo.—This armored cruiser, built at the Government dockyard in Castellamare di Stabia, completed her official trials a few months ago. Her principal dimensions are as follows: Length between perpendiculars, 327 feet; beam, 48.13 feet; draught amidship, 19.29 feet; displacement, about 4,527 tons.

The armament consists of six 6-inch, 40-caliber, Armstrong rapid fire guns, one of which is on the forecastle, one on the poop, and two in forward and after sponsons on each broadside; ten 4.7-inch, 40-caliber, Armstrong rapid fire guns, in broadside, the

two forward and the two after ones having ahead and astern fire; a number of smaller rapid fire and machine guns; and five torpedo tubes, one under water in the bow, and the other in broadside above water.

The twin-screw, four-cylinder, triple-expansion engines, built by Messrs. Ansaldo & Co., Sampierdarena, were designed for 6,000 and 10,000 I.H.P. under natural and forced draft (3 inches of water), respectively. The cylinders are 37, 56 and (2) 60 inches in diameter, the stroke being 30 inches. The H.P. cylinder is jacketed with steam of boiler pressure, the I.P. with 100 pounds, and the L.P. with 50 pounds. Piston valves are fitted to the H.P. cylinder, and slide valves to the others. Stephenson's link gear is used.

The propellers are of manganese bronze, four-bladed, 13 feet in diameter, and have a mean pitch of 15 feet.

There are two cylindrical bronze condensers with a total cooling surface of 23,680 square feet.

The four main, double-ended steel boilers have each six corrugated furnaces, and are 14 feet in diameter and 19 feet long. The total grate surface is about 601 and the heating surface, about 16,790 square feet. The grates are 7 feet 2 inches long. The working pressure is 150 pounds per square inch. The tubes are of steel. There is one smoke pipe for each group of two boilers; one of these groups is forward, and the other aft of the engines. There is besides an auxiliary boiler.

The total weight of machinery, complete in steaming condition, is about 800 tons. The contract price was about $500,000.

The trials were very much delayed on account of the work on the hull, and did not take place until last December and January.

The ten hours' natural draft trial, with four boilers, was made off Naples. The steam pressure varied between 135 and 150 pounds per square inch; revolutions were about 125.5; I.H.P., 7,150; speed, 17 knots; coal consumption, 1.9 pounds per I.H.P. per hour.

The three hours' forced draft trial gave the following results: Revolutions, 140; I.H.P., about 10,700; air pressure, about 2

inches; consumption of Cardiff coal, 2.14 pounds per I.H.P. per hour; speed, 19 knots.

The complement of the vessel is 17 officers and about 300 men.

Torpedo Boat.—The contract for this boat has recently been given to the works of N. Odero, Sestri Ponente. The length is to be 154 2 feet; beam, 16.92 feet; mean draught, 3.95 feet; and displacement about 133 tons. The engines are to develop 2,466 I.H.P. and give the boat a speed of 25 knots.

NORWAY.

Coast Defence Vessels.—Two vessels, to be of an improved *Svea* type, are now building. The general dimensions and requirements, as proposed, are as follows:

Length on load water line, 274.5 feet; beam, extreme, about 48 feet; draught, about 17 feet; displacement, 3,350 tons; I.H.P., natural draft, 3,650; speed, natural draft, 15 knots, forced draft, 16 knots.

There will be a central citadel, 9.57 inches thick.

The armament will consist of two 9.84-inch guns, one in each barbette turret, the latter surrounded by an armored revolving gun house; four 4.7-inch and six 2.24-inch rapid fire guns and ten machine guns.

The estimated cost of each vessel is about $950,000.

RUSSIA.

George the Victorious.—This first class battleship, built at Sevastopol, and some particulars of which were given on page 129 of Vol. IV, has satisfactorily completed her official trials. The general data are here repeated, and others from "Engineering" and "The Times," London, added.

The *Georgie Pobedonosetz* is a first class battleship of 10,280 tons displacement, 320 feet in length, 69 feet beam, and mean draught of 26 feet 7 inches, speed 16½ knots. The bunkers are capable of carrying 700 tons of coal. The armament consists of six 12-inch, 56-ton, breechloading guns of the Russian Krupp pattern, carried in three barbettes, two barbettes being placed abreast on the forward deck of the ship, each barbette carrying

two guns, the remaining two guns being situated in a barbette upon the after deck. There are also seven 6-inch, 6-ton, breech-loading guns, eight 3.94-inch quick firing, and six machine guns. The vital portions of the vessel are protected by a belt of 16 inches and the barbettes, by 12-inch compound armor-plates. The propelling machinery is of the vertical inverted triple-expansion type, having cylinders 45, 66 and 100 inches in diameter, and a common stroke of 4 feet, driving twin-screws of 16 feet 6 inches diameter. Working steam pressure, 150 pounds per square inch. Steam is supplied by 16 boilers arranged in four separate compartments. They are of the cylindrical single-ended type, having three furnaces each, the total grate area being 980 square feet, and total heating surface, 29,100 square feet. Air is supplied by means of 12 double-breasted fans, each 5 feet in diameter. On May 21, at 8·30 A. M., the vessel left Sevastopol Harbor for the official steam trial, the stipulated power being 10,060 to be maintained for six consecutive hours with assisted draught, ½-inch air pressure in the stokeholds being the maximum allowed. The trial commenced at 9·30 A. M., and was carried out under the direction of Mr. John Sampson, of Messrs. Maudslay, Sons, and Field, of London, the constructors of the machinery. The results were as follows:

	Steam pressure.	Vacuum in inches.	Revolutions.	Indicated horse power.	Total indicated horse-power.
1st hour, starboard	135	28	89	6,478.81	12,714.08
port	135	28	88	6,235.27	
2d hour, starboard	138	28½	89	6,379.27	12,680.61
port	135	28½	87½	6,301.34	
3d hour, starboard	150	28¼	92	7,067.39	13,890.49
port	150	28¼	90	6,833 10	
4th hour, starboard	140	28½	90	6,811.55	13,630.51
port	140	28½	90	6,818.96	
5th hour, starboard	145	28½	92	6,821.25	13,991 08
port	145	28	91	7,169.83	
6th hour, starboard	140	28½	91	6,782.56	13,900.41
port	140	28	91	7,117.84	
Total mean indicated horse-power					13,468

The mean air pressure in the stokehold was .25 inches. The coal was unpicked Nixon's Navigation, having 20 per cent. small. The result is considered highly satisfactory, the above mentioned horse power (nearly 3,000 in excess of the contract) being maintained with ease by the ordinary ship's crew of Russian stokers and artificers, led by a small staff of Englishmen. The ship returned to harbor in the evening. Upon the following day the vessel again put out to sea for artillery trials, the results of which were highly satisfactory, both guns and mountings being thoroughly tested during a trial which lasted nearly twelve hours. The *Georgie Pobedonosetz* will now join her sister vessels, *Sinope*, *Catherine II*, *Tchesma* and *Dvenatdset Apostoloff*, forming together a fleet of five first class battleships complete and equipped ready for service. The last ironclad launched in the Black Sea, *Tria Sviatitelia*, awaits steam trials.

General Admiral Apraxine.—This coast defense vessel, described on page 839 of Vol. VII, was successfully launched on Tuesday, May 12.

Rossija.—This triple-screw armored cruiser was successfully launched on Tuesday, May 12, at St. Petersburg. As built, she is a larger and more powerful *Rurik*, a description of which was given on page 433 of Vol. VII. She is the longest vessel ever launched on the Neva and the largest Russian vessel of the kind afloat. The keel was laid June 1, 1895.

The *Rossija* is 473 feet long on water line; length over all, 483 feet; beam, 68.5 feet; mean draught, about 25 feet; displacement, 12,195 tons. The total coal carrying capacity is said to be 2,500 tons.

The belt armor, 9.84 inches thick, extends over three-fourths the length of the vessel. The athwartship armored bulkheads at the ends of the belt are 8.86 inches thick forward and 7.87 inches thick aft. These armor plates are from the Carnegie mills, Homestead, Pa. The protective deck is 1.97 inches thick in the center and 2.76 inches at the sides.

There are 149 water tight compartments. Fourteen boats will be carried, including four third class torpedo boats.

The armament will consist of four 8-inch guns in sponsons, two forward and two aft; sixteen 6-inch, six 4.7-inch, and numerous smaller rapid fire guns; and four torpedo tubes.

The engines are of the vertical, inverted, triple-expansion type and are expected to develop 17,000 I.H.P. Each side engine is to develop 7,250 I.H.P. and the middle one, 2,500 I.H.P. They were built by the Baltic Works, St. Petersburg. The expected speed with full power is between 19 and 20 knots. With the middle engine alone, a speed of 9 knots is expected.

There are 32 Belleville boilers, arranged back to back in four separate fire rooms. The furnaces are fitted for burning coal and also liquid fuel. The total grate surface is 1,510, and the total heating surface, 47,131 square feet.

Pallada and **Diana.**—These cruisers have been laid down on the Neva.

SAN DOMINGO.

Restauracion.—This gunboat, constructed by Messrs. Napier, Shanks & Bell, Yoker, was launched May 15. The length is 213.25 feet; beam, 30 feet; tonnage, 563.

The armament consists of nine Hotchkiss rapid fire guns.

The twin-screw engines, which were designed to give a speed of 14 knots, were built by Messrs. Dunsmuir & Jackson, Govan. There is one cylindrical boiler, fitted with the builders' forced draft system.

The *Restauracion* is a larger, faster and better *Independencia*, built by the same firm for the government of San Domingo.

On the official trial, July 6, a speed of nearly 15 knots on the measured mile was attained.

SPAIN.

Almirante Oquendo.—The results of the forced draft trial of this cruiser, mentioned on page 841, Vol. VII, are as follows, I.H.P., 13,000; revolutions per minute, 117; speed, 20.3 knots.

MERCHANT STEAMERS.

Kherson.—This steamer, the thirteenth of the Russian Volunteer Fleet Association, and data of which were given on pages 618, 791 and 852 of Volume VII, had her trials on Saturday, May 16, off the Northumberland coast. The following additional particulars of the vessel and machinery and the trial data are from "Engineering," London.

The displacement at the load draught of 24 feet is 10,225 tons.

The ship is built of ordinary mild steel on the logitudinal cellular bottom principle, and will take about 900 tons of water in the double bottom. She has 10 water tight bulkheads extending to the upper deck. The machinery space is 156 feet long, 39 feet being devoted to the engine room, the other 117 feet being occupied by three boiler rooms, each 39 feet long by 32 feet wide, and each containing eight Belleville boilers. The bunkers are placed entirely at the sides, the great length of the stokehold enabling cross bunkers to be dispensed with. Provision has been made for special strengthening of the hull at the gun positions. There will be three 4.7-inch rapid fire guns; two on the forecastle, one on each side, the third on the poop. There are also twelve 2.95-inch guns, six on the upper deck forward and six aft. On the bridge deck, there will be eight 1.85-inch guns, four on each side.

The guns and ordnance supplies are kept in store at Odessa, so as to be readily put in place in time of war. There are five cargo hatches, one being large enough to take a full sized locomotive. There is a steam laundry, and a bakery fitted with modern machinery, capable of supplying sufficient bread for all on board. The ship is lit throughout by electricity.

The two pairs of triple-expansion engines are of the usual type, having cast-iron A-frames back and front. The cylinders are 36, 57 and 92 inches in diameter by 54 inches stroke. The

valve gear is on the Marshall system. The high pressure valve is a piston valve and has an interior expansion valve. The working pressure at the engines is 160 pounds. There are two condensers having a total cooling surface of 15,500 square feet. The propellers are 17 feet 6 inches in diameter by 25 feet pitch. Messrs. Maudslay would have used steel tubes, but were prevented by the Board of Trade, the ship being built to pass the Board of Trade examination and class at Lloyd's. We understand, however, that the Board of Trade have now consented to accept steel tubes in the boilers of this description, and a few have been placed in these boilers, whilst the eight spare tube sections, or "elements," have steel tubes. The makers of the Belleville boiler distinctly prefer steel tubes. The total grate surface is 1,132, and the total heating surface, 35,352 square feet, the latter calculated as follows:

The total length of the tube section is measured over all—*i. e.*, the length of the exposed part of the tube added to the length of the headers into which it passes—and this is taken as the length of the tube. This measurement is multiplied by the external circumference, and the product thus obtained is multiplied by the number of tubes. To this is added the rectangle inclosing the end of the headers in elevation, these ends naturally being exposed to the hot gases. The steam drums, being outside the influence of the gases, are not counted.

The space occupied by the boiler rooms and the following particulars as to weights have been kindly furnished by the makers, Messrs. Maudslay, Sons, and Field.

The boilers are heavier than the contractors consider they need be, in consequence of the demands made by the Board of Trade.

The actual weight of the twenty-four boilers, as designed, was 415 tons. This includes boilers and fittings to the base of the funnels, firebars, firebrick, feed regulators, safety valves, stop valves, lagging, &c. The funnels, three in number, are 9 feet 6 inches in diameter and 88 feet 6 inches high above grate bars. The weight of water, 24 tons at working level, would be additional. This would be for hot water at the usual working level of half glass.

This would fall to quarter glass when the engines were not taking steam. For half glass solid hot water, the weight would be 30 tons. In each of the six stokeholds, (each boiler room has two stokeholds), there are one main and one auxiliary feed pump, the actual weight being 1 ton, or 12 tons in all. There are six air pumps for supplying air jets just above the furnace doors to mix the gases and get more perfect combustion in the furnaces. The actual weight of all these is 6 tons 13 hundred-weight. In the engine room are two main steam and water separators, the actual weight being 2 tons each, or 4 tons in all. The two engine reducing valves are 1 ton 15 hundred-weight, or 3 tons 10 hundred-weight in all. The stokeholds are fitted with fans, and these were running during the trial. Their weight, however, is not included, as they were not worked at the request of Messrs. Maudslay, and were not required to keep the steam pressure up. The stokeholds are open. The above weights, which do not include spare gear, bring the total weight to 471 tons 8 hundred-weight, allowing solid water to half glass. The estimated weight for the boilers and auxiliaries was 504½ tons, so there was a saving in actual practice of over 33 tons. The contract power was 12,500 indicated horse power, but on the twelve hours' trial this was exceeded, the aggregate mean being 13,307. Accepting the above weights as a standard of what should be included under the heading of boilers, we have approximately 28 horse power per ton weight of boiler. It will be interesting to compare these figures as to weight with those in a recent example with cylindrical boilers.

H.M.S. *Renown*, the most recently tried of the big battleships, was engined by the same contractors who supply the *Kherson's* boilers. (An account of the full speed trial was given on page 387 of the May number of the JOURNAL.) On the forced draft trial, when the air pressure was only $\frac{7}{10}$-inch, the total mean indicated horse power was 12,901 for the four hours' run. The *Renown* has eight single ended return tube boilers, 16 feet 6 inches in diameter and 10 feet 3 inches long. The total grate area is 793 square feet, and the heating surface, 24,840 square feet. Messrs. Maudslay have been good enough

to give us the total weight of the *Renown's* boilers, which is 534 tons for boiler, fittings and water. This figure is supplied as corresponding to the 471 tons of the *Kherson's* boilers, and gives approximately 24 indicated horse power per ton of boiler. It must be remembered, however, that the *Kherson* ran for 12 hours with natural draft and with bad coal.

It is not a satisfactory method of procedure to estimate boiler efficiencies in terms of horse power, but we have, for our present purpose, no more exact data. In the instance under consideration, however, the figures given may be taken, so far as they go, as giving a fairly close comparison, for engineers of such high standing as those who supplied the engines of the *Majestic* and the *Kherson* are not likely to be far out in their designs. It should be remembered, however, that the *Renown* is a purely fighting ship in which running at high speed is a first consideration, whilst the *Kherson* is intended chiefly for a peaceful career and a speed of about 12 to 14 knots.

The above details as to weights of the *Kherson's* boilers have been supplied by the makers, and may, of course, be accepted as accurate; but they may not, and indeed do not, include all the details which some engineers are in the habit of classing under boiler weights. It is a fact which shows the necessity of an authoritative body—say a committee of the Institution of Mechanical Engineers—to standardize our expressions in such matters. The builders of the vessel, to whom the makers of the boilers are sub-contractors, perhaps not unnaturally take a rather different view of the weights. They have been good enough to supply us with a few figures bearing on this subject.

The *St. Petersburg* is a similar vessel to the *Kherson*, and was built for the same owners a short time previously. The weight of her double-ended return tube boilers for 13,000 indicated horse power would have been 795 tons, including smoke boxes, funnel, furnace fittings, mountings and water. The Belleville boilers of the *Kherson*, with fittings and water, were 544 tons. To this Messrs. Hawthorn add 35 tons for extra pumps and air blowers, reducing valves, separators, &c., and 18 tons for additional seatings over those which would have been required for cylindrical

boilers. With ordinary shell boilers, two funnels would have been sufficient, but the three boiler rooms of the Belleville arrangement necessitated a chimney to each one, and these chimneys with Belleville boilers require heavy beams to support them. It is estimated that this gives an additional 12 tons, so that the total weight is brought up to 609 tons for the Belleville boilers of the *Kherson*. This, of course, is a very different figure to Messrs. Maudslay's 471 tons, but it will be seen that additional things have been included, such, for instance, as stokehold floor plates, gratings, funnels, &c. Whether these should be counted as "boiler" or not is a matter of opinion. No doubt, to arrive at a definite conclusion as to the respective values of types of boilers, they should be added, as the boiler room of the *Kherson* is longer than would be necessary with ordinary boilers, and that means additional floor plates.

The length of the boiler space is 117 feet in the *Kherson*. In the sister ship it was 97 feet, including the cross bunkers. The loss was, therefore, 20 feet in the length of the ship. It should be added, however, that the *Kherson* gave more than 13,000 indicated horse power, on which the above figures are based, and, so far as the boilers were concerned, there was no doubt steam for a much higher power could have been supplied. The same could be said of the whole machinery, but the contract was of a very stringent nature, and the contractors were bound to a limit of piston speed.

The results of the trial are as follows: The mean speed for the 12 hours, as ascertained by running the long measured course off the mouth of the Tyne, was 19.5 knots; mean revolutions, 89.8; steam pressure at engines, 157.3 pounds, at separators, 225.2 pounds; vacuum, 27.05 inches; and mean I.H.P., 13,307. The whole trial was conducted without a hitch, the engines running perfectly.

During the twelve hours' trial the boilers worked admirably, giving steam at the pressure required without trouble. The coal used was mostly Welsh, more than half being little more than dust, and later, some North country coal.

[NOTE.—From the figures given above it will be found that, for the *Kherson*, the I.H.P. per square foot of heating surface is .376, and per square foot of grate surface, 11.76; similar ratios for the *Renown*, under natural draft, are .431 and 13.5, respectively. From the figures given for the forced draft trial of the *Renown*, the I.H.P. per square foot of heating surface is .519, and per square foot of grate surface, 16.27.—EDIT.]

Kiev.—This twin-screw steel steamer, built for the Russian Volunteer Fleet, was launched by Messrs. J. & G. Thomson, Clydebank, on February 18. The length is 419 feet; beam, 49.5 feet; depth, 32 feet. The engines are triple-expansion and the propellers of bronze. The estimated sea speed is 12 knots.

Puri.—This steel twin-screw steamer was built and engined by Messrs. Gourlay Brothers and Co., Dundee, to the order of the India General Steam Navigation Company, of Calcutta, to meet the increased requirements of their passenger and carrying trade between Calcutta and Chandballi. The following description is from "Engineering," London.

The *Puri* is 260 feet long between perpendiculars, 35 feet beam, having a gross tonnage of 936 tons. She was designed to carry a large cargo on a light draught of water at a high rate of speed, namely, 17 knots. All the decks and woodwork are of teak. Upon the shade deck there is a large deck house forward of the machinery, containing accommodation for a few European passengers. The main and 'tween decks fore and aft are set apart for the accommodation of native passengers. On the main deck are four powerful steam winches, supplied with steam by a special boiler. The cargo hatches are placed at each side, instead of in the center of the deck. The vessel is lighted throughout by electricity.

The twin-screw engines are of the triple-expansion type, with cylinders 21, 33 and 52 inches in diameter, the stroke being 30 inches. Several departures from the ordinary practice have been followed in these engines. The bedplates of the engines, although made separate, are bolted together, while the cylinders of port and starboard are connected at top, with supporting columns

placed in the center, a system which Messrs. Gourlay have adopted to distribute the weight and strains over a wider area of the ship's bottom, and to minimize vibration. The high pressure cylinder is between the low pressure and intermediate, and the working parts of both engines face the center line of the vessel. There are the usual A-frames at the back. The engines are 10 feet 3 inches apart from center to center.

The piston valve of the high pressure cylinder and the slide valve of the intermediate cylinder are close together in one casing. The low pressure cylinder has a slide valve, both intermediate and low pressure valves being fitted with balance pistons. All the working parts of the engine and the whole of the shafting are of Siemens-Martin steel. The crankpins are hollow and fitted with centrifugal lubrication. The guide bars are made from two Siemens-Martin steel plates, with distance plates between, and having water circulation up the center. The oil pipes are carried down in between, with outlets at various positions in the length of the bars. One bar serves both for go-ahead and go-astern motion. The reversing engines are of the builders' own direct-acting steam and hydraulic type. All the handles for operating the machinery, the telegraphs, pressure gauges, drains, &c., are concentrated on the center column between the engines. The condensers are short and high, affording unusual facilities for getting about the main bearings for overhauling from both sides. The thrust blocks are incorporated with the bed plates, insuring absolute rigidity. The air pumps are worked by levers from the L.P. crosshead. The circulating pumps are of the ordinary centrifugal type. The propellers are 11 feet 9 inches apart between centers. Each is 10 feet in diameter by 13 feet pitch, with three manganese bronze blades bolted to steel bosses. They work outwards.

The two-armed propeller brackets are solid forgings without welds, and were forged outwards from the boss. The lower arms are about 3 feet long, securely riveted to the keel, and the upper arms are about 6 feet long, riveted to the shell and frames of the vessel. The builders decided to adopt solid forged brackets in preference to the usual cast steel, as they regarded the former

as much stronger and more reliable. The bracket and stern tubes are bushed with a special mixture of white metal, and the propeller shafts have no gun metal bushes. Messrs. Gourlay have fitted a large number of both single and twin-screw steamers in a similar manner with most satisfactory results, especially when the vessels (as in the present case) navigate sandy waters. The corrosion usually set up by the ordinary brass bush arrangement is also obviated.

There are two double-ended main boilers, 13 feet 8 inches in diameter by 18 feet 9 inches long, having about 8,000 square feet of heating surface, and working at 160 pounds pressure. The closed fire room system of forced draft is used, there being a large double inlet Capell blower in each of the two fire rooms.

During the trials the machinery gave the utmost satisfaction, while the speed and other performance of the vessel exceeded the contract stipulations. The following mean result of two of the measured mile runs is fairly indicative of the whole:

Steam pressure, 150.5 pounds per square inch; vacuum, 27 inches; revolutions per minute, starboard, 172, port, 173; steam pressure in I.P. valve chest, 62.5, and in L.P. valve chest, 11.25 pounds per square inch: I.H.P., starboard, 1,962, port, 2,026. Total I.H.P., 3,988.

———.—This steamer, referred to on page 208 of the February number, building by Mr. F. Schichau at the Danzig yard, for the North German Lloyd, will be one of the largest and fastest of the Atlantic steamers. The following particulars are from the "Nautische Rundschau," Vienna:

Length over all, feet	580 (?)
Beam, extreme, feet	64
Depth of hold, feet	41
Draught, full load, feet	28.25
Displacement, tons, about	17,500
Speed, to be maintained for 6 hours, knots	22.5

The vessel is to maintain a service speed of 21 knots, guaranteed for two years, on a mean draught of 28.25 feet (winter voyages excluded). The hull will be of Siemens-Martin steel, having a double bottom extending the whole length, and 14

transverse water tight bulkheads, 13 of which will extend to the upper deck. There will be a longitudinal midship bulkhead in the machinery spaces. Bilge keels will be fitted. There will be cabin accommodations for 274 first and second class passengers, and room for 780 steerage passengers. There will be two pole masts with fore-and-aft sails. She will carry 16 steel life boats, each 30 feet long.

The carrying capacity will about 5,000 tons, distributed as follows: Coal, 3,700; fresh water in double bottom, 200; passengers and crew, 200; provisions, 200; and freight and baggage, 700.

The twin-screw engines will be of the five-cylinder, quadruple-expansion type, the cylinders being arranged as follows: The H.P. and the first L.P. cylinders, and the first I.P. and second L.P. cylinders, are tandem fashion over the forward and middle cranks, respectively; the second I.P. cylinder works the after crank alone. Piston valves will be fitted on the H.P. and first I.P. cylinders only, the others having slide valves. Link gear will be used.

The cylinder diameters are to be 36.09, 53.48, 76.77 and (2) 77.76 inches, the stroke being 55.78 inches. The cooling surface of condensers will be about 40,900 square feet. An independent circulating pump in each engine room will be large enough to supply both condensers, in case of emergency. The main air pump, two feed, two bilge and two flushing pumps will be worked from each main engine. There will be, besides, in each engine room, one duplex feed pump, large enough to feed all boilers; one auxiliary feed pump; one fire pump, and one Weir's duplex feed pump with feed heater.

Two Morison evaporators, with a capacity of 90 tons, and one distiller, with a daily capacity of 18 tons of potable water, two feed water purifiers, and a duplex ballast pump, capable of an hourly discharge of 250 tons, five ballast pumps, each capable of discharging 100 tons per hour, and four bilge ejectors, together capable of discharging 360 tons per hour, will also be installed.

There will be three ash hoisting engines and six ash ejectors, patented by Mr. Horace See, New York.

The crank and propeller shafts will be of nickel steel, with an outside diameter of 19.68 inches, and have a 7.284-inch hole. The line shafting will be of Siemens-Martin steel, 18.86 inches in diameter. The propeller shafts will be fitted with a bronze casing, .984 inches thick, the outboard parts of which will be coated with Willenius' patent gum preparation.

The propellers will be of bronze, each 20.34 feet in diameter, and have a pitch of 32.81 feet.

There will be nine double-ended and one single-ended boiler, arranged in three compartments, and three smoke pipes. The diameter of the boilers will be 16.73 feet, and the thickness of shell plates, 1.246 inches. The total grate surface will be 1,442, and the heating surface, 76,430 square feet. The working pressure will be 220 pounds per square inch.

Another fast steamer for this company is building by the Vulcan Works, Stettin. Mr. C. F. Laeisz, in his paper read before the recent Hamburg meeting of the Naval Architects, gives the dimensions of this steamer as follows: Length between perpendiculars, 625 feet; beam, 66 feet; moulded depth, 43.

The I.H.P. of the twin-screw engines is to be 28,000.

Adria and **Armenia.**—These two steel emigrant and freight steamers, built by the Palmer Shipbuilding and Iron Co., Jarrow-on-Tyne, for the Hamburg-American Steam Navigation Co.'s Atlantic service, were successfully launched on May 27 and June 27, respectively.

The length of these vessels is 400 feet between perpendiculars; beam, 50 feet; moulded depth, about 30 feet 3 inches; deadweight capacity, 7,000 tons. These vessels have been built under the requirements of the German Lloyd's highest class. They are of the three-deck type. A double bottom for water ballast runs the whole length of each vessel, with a center line bulkhead dividing the two sides. Pumping out pipes lead to each compartment of the double bottom. There is accommodation for about 350 emigrants, Hoskin's patent berths being fitted on each side in separate rooms for ten persons each. The space between is clear and is used for the dining tables and seats. All the fittings in this space are movable, so that they can be removed

and the space occupied by cargo or cattle. Electric lights, refrigerating and ventilating machinery and other improvements are provided.

The engines are of the four-cylinder, quadruple-expansion, Schlick self-balanced type, with cylinders 22.5, 32, 47 and 68 inches in diameter, the stroke being 51 inches. The designed I.H.P. is 2,500 and the speed 11 knots, laden. There are three cylindrical boilers, one double and two single-ended, the working pressure being 210 pounds per square inch.

Asturia.—This steel emigrant and freight steamer, built by the Palmer Shipbuilding and Iron Company for the Hamburg-American Steam Navigation Company, was launched on March 17, and completed her official trial on Saturday, May 23.

The general arrangement is the same as that of the other two steamers, *Adria* and *Armenia*, described above. The dimensions differ slightly, and the engine is of the triple, instead of quadruple-expansion type.

The length between perpendiculars is 390 feet; beam, 53 feet; moulded depth, about 29 feet.

The engine cylinders are 27, 45.5 and 74 inches in diameter, and the stroke is 48 inches. There are three single-ended boilers, each 15.75 feet in diameter and 11 feet long, the working pressure being 180 pounds per square inch.

On the trial, the revolutions were about 78 per minute, the mean speed on the measured mile being 12.5 knots.

Sir Henry Bessemer and **Sir William Siemens.**—The first steamer of the Bessemer Steamship Co.'s new fleet, the *Sir Henry Bessemer*, was launced by the Globe Iron Works Co., Cleveland, Ohio, on Saturday, May 9. She is one of seven steamers building for the "Rockefeller fleet." The *Sir William Siemens*, built by the same company, was launched on July 25.

The dimensions of these vessels are as follows: Length over all, 432 feet; length between perpendiculars, 412 feet; moulded beam, 48 feet; moulded depth, 28 feet; depth of water ballast tank, 5 feet.

The steamer has main deck beams but no laid deck, except at the forward and after ends; also a forecastle deck forward, and

one steel deck house forward, as well as a steel pilot house. She has also a steel deck house on the spar deck aft, with galley and dining rooms on main deck aft. Engines and boilers are placed aft, between decks, the boilers athwartships, with fire room between them. The boiler house is of steel, and the coal bunker, next forward of the boilers, is carried up to the height of the boiler and deck house aft. The spar deck is of steel, without wood covering except inside the houses and on the forecastle deck. The ship has two pole masts.

All plating is of open hearth mild steel, tested, according to the specifications, as follows: Tensile strength not less than 54,000 and not exceeding 62,000 pounds per square inch; limit of phosphorous not to exceed .08; elongation to be not less than 24 per cent. in 8 inches, and radiation to be not less than 45 per cent. Plates not to be run over or under theoretical weight more than $2\frac{1}{2}$ per cent. Rivets of first class quality of iron rivet-material of not less than 50,000 tensile strength. Materials to be tested at maker's works to these requirements by a disinterested party to represent both steel maker and ship builder; provided, that in case of angles, channels, beams and Z bars, the certified reports of tests made at the laboratory of the Pencoyd iron works will be accepted by the owner.

The engine is of the vertical, inverted, triple-expansion type, having cylinders 25, 41 and 66 inches in diameter with a stroke of 42 inches. Thickness of metal for the high pressure cylinder is $1\frac{3}{8}$ inches, intermediate pressure, $1\frac{1}{2}$ inches and low pressure, $1\frac{5}{8}$ inches. The cylinders are supported by cast iron columns of rectangular cross section at back and front of engine. The bed plate is of box form and of cast iron, 21 feet 5 inches long and 11 feet in width. The high pressure cylinder has a piston valve, the intermediate and low pressure cylinders, double ported slide valves. The valve gear is the usual link motion, with two eccentrics; the steam reversing engine is attached to the housings at the front. The pistons are of the usual box form, each being fitted with spring rings. Piston rods are made of the best steel and are $5\frac{5}{8}$ inches in diameter. The connecting and eccentric rods are of wrought iron. The condenser and air pump are placed at

the back of the engine, the pump being worked from the cross-head of the intermediate cylinder.

Boilers are of the Scotch type, four in number, each 11 feet 3 inches mean diameter by about 11 feet 11½ inches long. Each boiler has three furnaces of 36 inches inside diameter, and the total heating surface is about 6,300 square feet. The working pressure is 175 pounds per square inch. The propeller is 14 feet in diameter and has a pitch of 16 feet. There are two steam capstans amidships and one aft, and a steam capstan windlass forward. A complete electric lighting outfit is furnished by the General Electric Company.

John Ericsson.—Another steamer of the new fleet of the Bessemer Steamship Company was successfully launched in the middle of July by the American Steel Barge Company, West Superior, Wis.

The length is 404 feet; beam, 48; depth, 27 feet; carrying capacity, on a draught of 14.5 feet, about 4,000 tons. The general construction is similar to the new lake steamers. There are two steel deck houses, one forward and the other aft.

The triple-expansion engine, with cylinders 25, 40 and 68 inches in diameter, and a stroke of 42 inches, are in the extreme after end of the vessel. There are three cylindrical boilers, each 13 feet in diameter by 13 feet long. The machinery was built by the Cleveland Shipbuilding Company.

E. W. Oglebay.—This steel steamship, built by Messrs. F. W. Wheeler & Co., West Bay City, Mich., for David Whitney of Detroit, was launched on Saturday, May 16. The following data were kindly supplied by the builders.

This steamer has the following dimensions: Length over all, 386 feet 9 inches; length on keel, 366 feet; beam moulded, 45 feet; depth moulded, 26 feet 7 inches.

The machinery consists of a triple-expansion engine, with cylinders 23, 37½ and 63 inches diameter and a stroke of 44 inches. There are three cylindrical return-tube boilers, each 12 feet 6 inches diameter and 12 feet long, fitted for natural draft, and working at 170 pounds' pressure.

Queen City.—This steel steamer, built by the Cleveland Shipbuilding Co., for the Zenith Transit Co., was successfully launched on Saturday, May 9.

She is built of open hearth mild steel, is 400 feet long over all, has a beam of 48 feet, and is 29 feet deep at the shallowest point amidships, with about 6 feet sheer forward and 4 feet aft. The double bottom, 5 feet deep, is divided into 8 compartments and will hold about 2,500 tons of water ballast.

The engine is of the triple-expansion type, with cylinders 21, 38 and 63 inches in diameter, the stroke being 40 inches. The propeller is 13.5 feet in diameter.

The Babcock & Wilcox boiler plant is a duplicate of that of the *Zenith City*, described on page 765 of Vol. VII.

Reina de los Angeles.—This steamer, described on page 427 of the May number, completed a successful trial on Saturday, June 27, making 13 knots without forcing.

Senator.—This steel steamer, built by the Detroit Dry Dock Co. for the Wolverine S. S. Co., Cleveland, is one of the largest on the lakes. She was successfully launched in June.

The following particulars are from the "Marine Record," Cleveland:

The length is 424 feet over all; beam, 45.5 feet; depth of hold, 28 feet. The carrying capacity is estimated at 4,400 tons on a draught of 16 feet. With this load a speed of 13 miles per hour is expected. There are twelve hatches, two of them being forward of the pilot house. The double bottom, divided into five compartments, has a capacity of 2,052 tons of water.

The engine is of the triple-expansion type, with cylinders 22, 36 and 58 inches in diameter, the stroke being 44 inches. The I.H.P. is estimated at 1,400. There are two cylindrical boilers, each 13.5 feet in diameter and 12 feet long, and fitted with Howden's forced draft system. The working pressure is 165 pounds per square inch. The propeller is 14 feet in diameter.

The weight of the vessel is approximately 2,000 tons.

Inchmona.—This vessel, particulars of which were given on page 422 of the May number, had satisfactory trials on May 4 and 5.

The cylinders are 17, 24, 34, 42, and 42 inches in diameter, the stroke being 42 inches. The valve gear, which is of the ordinary link motion type, is unusually light, owing to the smallness of the valves. The small size of the low pressure cylinders enables the centers of the engines to be closer than usual, and the engines go into a compartment only one frame space longer than is usual with the three-crank engine.

The five cranks are set at equal angles. The crank shaft, "built up" of the finest ingot steel, is in five interchangeable sections. The engines were designed to run at 100 revolutions per minute.

A water meter, made by Mr. W. Kennedy, Jr., of Kilmarnock, forms part of the engine room equipment. Edmiston's feed water filters and a Mudd's evaporator are fitted. All the piston rods and spindles are packed with the metallic packing manufactured at the Central Engine Works.

The engine room telegraph is of a special type, manufactured by Messrs. Mechan and Sons, of Glasgow, and known as the "Triple Automatic," the special feature of which is that there is a third pointer actuated by the engine, so that any mistake made in the setting or reversing of the engine is at once apparent to the attendant.

The two cylindrical boilers are single-ended, each 11 feet in diameter, 10 feet 6 inches long, and have "Purves" patent furnaces.

The boilers, which were tested to twice the working pressure, or to 510 pounds per square inch, are besides fitted with Mudd's superheating apparatus, Serve tubes and retarders. Ellis & Eaves' system of suction draft is used. Combined with the superheater are an apparatus that Mr. Mudd calls an initial receiver, an exceptionally complete system of steam jacketing to the cylinders, and an exhaust control arrangement. There is also an unusually elaborate scheme of feed heating. Instead of the usual single vessel, there are a series of feed heaters worked at graduated temperatures, and, as the water passes through these, it continues to rise in temperature, until, on entering the boilers, it is nearly at the temperature of the steam. On the trials, the

temperature of the feed water, as it passed the meter and entered the boilers, was about 400 degrees Fahrenheit.

The average consumption of north-country coal on the trials is given as 1.07 pounds per I.H.P. per hour. Steam was easily maintained at 255 pounds pressure, the engines running steadily at about 80 revolutions per minute, with the induced draft fan running at a speed of 180 to 200 revolutions per minute. No difficulty of any kind arose, and at the conclusion of the trials the vessel proceeded on her first voyage up the Baltic. The coal used during the trials was carefully weighed for four separate runs in the presence of four separate groups of visitors, who were taken off to the vessel by tug. On the first run, the consumption was 1.142 pounds of coal per horse power per hour; on the second run, 1.078 pounds; on the third run, .999 pounds; and on the fourth, 1.069.

If the anticipations of the builders are realized, it will mean that some 500 to 600 tons of coal can be saved on the single round voyage to Australia or New Zealand of a cargo ship carrying 6,000 or 7,000 tons at a speed of eleven knots.

Ellen, Elizabeth and **Marie Rickmers.**—These steamers, particulars of which were given on page 425 of the May number, completed satisfactory trials in May. These vessels are intended mainly for the rice trade between Bremen and China.

The *Ellen* and *Marie Rickmers* were built by Messrs. J. L. Thompson & Sons, Sunderland, the machinery of the former having been built by Messrs. John Dickinson & Sons, Sunderland, and those of the *Marie Rickmers*, by Messrs. George Clark, Sunderland. The engines of these two steamers are of the same size, the cylinders being 27, 43 and 72 inches in diameter, with a stroke of 48 inches. The *Ellen Rickmers* has three cylindrical boilers working with Howden's forced draft system, and the *Marie Rickmers*, four cylindrical boilers working under natural draft. The steam steering gear is placed in the after end of the engine room and is controlled by a wheel from a house on the bridge deck forward. All the deck machinery, consisting of anchor hoist and numerous winches, is arranged to work at 180 pounds pressure.

Dunvegan Castle.—This steel passenger steamer, built by the Fairfield Shipbuilding and Engineering Co., Govan, Scotland, for the Castle Mail Packets Co., London, was successfully launched on April 17. The principal dimensions are: Length, 465 feet; beam, 51 feet; depth, 35 feet; and a gross tonnage of about 6,000. The cellular double bottom extends the whole length of the vessel. There are ten water tight bulkheads.

Accommodation is provided for about 280 first class, 100 second class, and 80 third class passengers, and arrangements have been made for the extension of the third class accommodation when required. The first class dining saloon, about 50 feet square, is situated on the main deck, the first class smoking room on the bridge deck, and the drawing room on the promenade deck. The second class saloon is in the fore part of the ship, the smoking room being on the upper deck, while the third class passengers are berthed forward on the main and lower decks. A refrigerating plant is fitted on board, and properly insulated cold chambers are provided for the conveyance of both fresh meat and fruit.

There are seven steam winches and a complete outfit of steam windlass and warping capstans. There is a steam steering gear aft and the usual hand gear.

The engines are triple-expansion. The H.P. cylinder has a piston valve, and each of the other two cylinders, a double ported slide valve, all worked by double eccentrics and links. The shafting is of ingot steel. The four propeller blades are of manganese bronze. There are five cylindrical, steel boilers, three being double-ended and two, single-ended; the working pressure being 170 pounds per square inch. Each double-ended boiler has six, and each single-ended boiler, four furnaces, making a total of 26 furnaces.

The vessel is lighted throughout by electricity, three Siemens dynamos, direct driven by compound engines, supplying the current.

Longmoon.—This steel steamer, built and engined by Messrs. Wigham Richardson and Co., of Newcastle-on-Tyne, for the Chinesische Küstenfahrt Gesellschaft of Hamburg, completed a

satisfactory trial trip on May 23. The vessel is 310 feet in length by 38½ feet beam and is rigged as a two-masted schooner.

She has been specially constructed for the Eastern coasting service of this company, and has handsome, well ventilated, and convenient accommodation for a large number of native and European passengers. The engines are of the quadruple type, self balanced on the Yarrow, Schlick and Tweedy system. During the trial trip they worked most satisfactorily, driving the vessel at a speed of 12⅝ knots.

Carlow.—This steel screw steamer, built and engined by Messrs. Blackwood and Gordon, Port Glasgow, for the City of Dublin Steam Packet Company, Dublin, made her official trials on May 19.

Her length is 260 feet; breadth, 34 feet; depth to main deck, 16 feet 9 inches, with full poop, long bridge and forecastle, having short breaks filled in with planking, which gives a continuous upper deck; gross tonnage, 1,284 tons. The vessel has been built very much in excess of Lloyd's scantlings and is fitted with deep rolling chocks.

Accommodation is provided for about 100 passengers. Provision has been made for carrying 500 cattle below, and sheep on the upper deck.

The triple-expansion engine is to develop fully 3,000 horse power. There are two double-ended, cylindrical boilers with a working pressure of 170 pounds per square inch. The propeller is of bronze.

The trials were highly satisfactory, the mean speed for the four hours' run being fully 15.25 knots per hour.

Sigurd.—This steel steamer, built for Mr. L. H. Carl, of Copenhagen, had a satisfactory trial trip on May 11. The length is 285 feet; beam, 39.5 feet, and depth, 19 feet. The hull is built with web frames and cellular double bottom, with a large ballast tank in the after peak.

The engines are of the three-crank, triple-expansion type, and were built by the Central Marine Engine Works, the cylinders being 21, 33 and 56 inches in diameter by 36 inches stroke. There are two large steel boilers working at a pressure of 160

pounds per square inch. The engines were run at full speed till the vessel had made several runs on the measured mile off Sunderland, the average speed with and against the tide being over 12 knots. The contract stipulated that the vessel should be capable of steaming 9½ knots light on 12 tons of coal per day. To satisfy this condition, the engines were reduced in speed and the coal weighed; it was found that she was capable of making 10½ knots on the measured mile on a consumption of 8 tons of coal per day.

Ulster.—The first of the four steamers of the City of Dublin Steam Packet Company, for the mail service between Kingston and Holyhead, was successfully launched on June 27 by Messrs. Laird Bros., Birkenhead. These vessels were partially described on page 623 of Vol. VII. The following data of the vessel, as finished, are from "Engineering," London:

The *Ulster* is of steel, 372 feet long; 41.5 feet beam; depth, 29.25 feet; registered tonnage, 3,069; load draught, 14.5 feet.

There are ten water tight compartments. If the two largest of these should become filled with water, the vessel would still be in a perfectly safe condition. The machinery consists of two independent sets of inverted direct-acting, triple-expansion engines, each set having one high, one intermediate, and two low pressure cylinders. The shafts, piston rods, connecting rods, &c., are of steel. The air pumps are vertical, one to each set of engines, worked from the piston rod crossheads. The circulating pumps and main and auxiliary feed engines, and powerful bilge and fire engines are all worked independently. The boilers are of steel, four in number, double-ended, each having six furnaces, Morison's corrugated, and the working pressure is 175 pounds per square inch. The boilers are to be worked on the closed stokehold system. The propellers are of manganese bronze. The electric light installation, which is in duplicate, is of very ample capacity. There will be two funnels, two pole masts, and a turtleback about 70 feet long, forward, and a flush upper deck, on which there will be three deck houses, containing the entrances to the cabins, smoke room, ladies' deck saloon, &c. On the main deck the cabins extend unbroken from end to end of the

ship, the machinery being entirely below the deck. The light and air shafts from the engine room are carried to the top of houses, forming "boat decks," so that the machinery is entirely out of sight. The first class dining saloon, situated on the main deck, forward of the machinery space, is 40 feet long and 34 feet broad, extending the full width of the vessel, with a seating capacity of about 80 passengers. The sleeping accommodation for the first class is arranged on the main deck, and there are also 14 first class state rooms on the lower deck forward and aft of the machinery. The ladies' first class cabin is on the main deck abaft the machinery space, and there is a ladies' deck saloon on the upper deck in the after deck house.

YACHTS.

Sovereign.—This steel twin-screw yacht, particulars of which were given on page 434 of the May number, was successfully launched at South Brooklyn, N. Y.

The *Sovereign* was designed by Mr. J. Beavor-Webb, of New York, the designer of the *Sultana*, *Corsair*, *Intrepid* and other yachts. When in commission, the yacht will draw 12 feet.

The following description is from the "Marine Journal," New York:

The steel plates are lapped below the water line, but worked fair above it. The steel decks are covered with selected pine. There is one large deck house which contains chart room, deck saloon, galley, upper fireroom, lavatory, storeroom, and entrance to engine room. Below this are the crew's quarters in the forecastle; abaft the forecastle are the officers' quarters, ten staterooms in all, with a mess room in the center, fitted in Honduras mahogany. Next comes the main saloon, fitted in San Domingo mahogany, and containing sideboards, an organ, piano and other necessary furniture. Abaft this saloon is the pantry, companion and a bath room. Abaft the pantry is the engine and boiler space. Abaft the engines is the owner's stateroom, which extends clear across the ship. This room will be painted ivory white with Honduras mahogany wainscot and doors. Aft of this room, on each side, are bath rooms and two good sized staterooms fitted up in the same manner. Between these is a passageway finished in Honduras mahogany.

Abaft of these rooms is the after saloon, finished in satin wood, and two state rooms and one bath room, fitted like the other state rooms. All the deck fittings will be of Honduras mahogany. The main deck aft is as clear of houses as a sailing yacht, and with much more room. There are 100 feet clear from the after part of the house to the taffrail.

The engines are of the triple-expansion type, with cylinders 15, 24 and 39 inches by 20 inches stroke, and were built by the W. & A. Fletcher Co., Hoboken, N. J.

The two boilers of the Babcock & Wilcox water tube marine type will furnish steam at 225 pounds pressure. The heating surface in each boiler is 3,500 square feet, and the grate surface, 72 square feet, giving a ratio of 48 to 1. As it is the intention to burn anthracite coal exclusively, only one furnace is used, which extends the entire width of boiler, four furnace doors being provided. The steam drums are 42 inches in diameter and 13 feet long, the heads being forged by hydraulic pressure; all joints are butt-strapped, and have six rows of rivets, every rivet in the drums being driven with hydraulic pressure and held until cold. Each boiler will contain about 10½ tons of water.

The closed fire room system of forced draft will be used. There is a steam steering gear, made by the Messrs. Williamson Bros., Philadelphia, and a steam windlass.

The yacht will have two pole masts, and carry six boats—two naphtha launches, a gig, a cutter, and two dinghys.

Margarita.—This twin-screw steel yacht, mentioned on page 213 of the February number, was launched by the Ailsa Shipbuilding Co., Troon, Scotland, on June 13. Her length over all is 280 feet, between perpendiculars, 246 feet; beam, moulded, 23.5 feet; depth of hold, 20 feet, and is of 1,350 tons, yacht measurement.

The vessel has topgallant forecastle and shade deck, and is schooner rigged with two pole masts. Forward, there is a large dining saloon surmounted by a dome, filled in with richly stained glass, and three large staterooms, children's room, pantry and bath rooms. Aft is the owner's stateroom, which extends the whole width of vessel, with dressing and bath rooms communicating. Abaft of this, there is a long passageway with guests' rooms, doctor's room, bath room, maid's room, and wardrobe room on either side. Further aft, there is a separate compartment with cabins entering from deck for stewards and servants. On the main deck amidships there is a large range of houses. At the extreme forward end is a large cabin beautifully fitted up as

a library, and at the after end a boudoir or drawing room. The cabins and staterooms are principally fitted up in polished mahogany. The machinery, building by Messrs. David Rowan & Son, Glasgow, consists of two distinct sets of quadruple-expansion engines, each having four cranks, and to work at a steam pressure of 200 pounds per square inch. The boilers are single-ended and forced draft will be used. There is a complete installation of electric lights and an arrangement of lamps for illuminating the ship and rigging; also a powerful search light; refrigerating machinery with ice rooms; a complete system of water heating throughout the rooms; and electric fans in the rooms. There is a powerful steam windlass, steam capstan and steam steering gear, the latter being placed aft and controlled by shafting from the bridge amidships. She has two steam launches, and two racing cutters, besides several other boats.

Willa-Walla.—This steam yacht is building by Mr. C. D. Miller, of Poughkeepsie, N. Y., for the Messrs. Frank.

The following description is from "Seaboard," New York: The length over all is 75 feet; length on water line, 71 feet; beam, 10.5 feet; draught amidships, 3.75 feet. Her lines are unusual, and she is expected to be very fast.

The frames of the vessel are of oak, the planking of yellow pine, and there is a steel keelson. The pilot house and the trimmings of the boat outside are of San Domingo mahogany, while the interior fittings of the vessel are of quartered oak. The main saloon is aft of the engine; forward of the boiler are the dining room, galley and quarters of the crew. All fittings of the vessel will be either brass or bronze.

The triple-expansion engine has cylinders 6½, 9 and 15 inches in diameter, with a stroke of 10 inches, and is expected to develop 100 horse power at about 350 revolutions. The diameter of the propeller is 38 inches. The propeller is under the keel, two feet from the stern. There is one Seabury water tube boiler.

Parthenia.—This steel steam yacht was launched from Roach's shipyard (the Delaware River Iron Shipbuilding & Engine Works,) at Chester, Pa., on Tuesday, June 9. She is

owned by Mr. Stephen W. Roach, and will be attached to the Larchmont Yacht Club fleet.

The *Parthenia* is 142 feet long over all, 115 feet 9 inches long on the water line, has a beam of 18 feet and a depth of hold of 9 feet. The draught, including a 1¼-foot shoe attached to the keel, is 7¼ feet. The yacht is schooner rigged. The gross tonnage is 140.91, and the net tonnage, 89.02.

The two deck houses are finished in polished mahogany, both outside and in, the dining room being forward. There are seven staterooms aft of the engine, with baths and the most approved sanitary arrangements. The galley has ample room and the latest improved appliances. The interior finishings in the saloon and staterooms are principally in white and gold, with mahogany highly polished for the rails and exposed work.

The triple-expansion engine has cylinders 9, 16 and 25 inches in diameter, the stroke being 16 inches. The propeller is three-bladed, 6.5 feet in diameter and has a pitch of 7 feet. There are two Almy water tube boilers with a total grate surface of 32 square feet. A speed of 18 knots is expected.

Scud.—This steel yacht, built by Mr. J. S. White, East Cowes, Isle of Wight, for Mr. A. H. E. Wood, had a successful trial on May 7, attaining a speed of over 20.25 knots, with about 550 I.H.P., 430 revolutions per minute, and a steam pressure of 200 pounds per square inch.

This vessel was designed and constructed on Mr. White's patent "turn-about" system, having the after deadwood cut away and double rudders put in. The steam steering gear is in the after peak and actuates a quadrant on the forward rudder. The yacht, in outward appearance, resembles a second class torpedo boat. On the turtle back forward there is a search light. Her length is 90 feet over all; beam, 10.75 feet; and depth, 5.5 feet.

The engines are of the three-cylinder, compound type, with cylinders 11, 17.5 and 17.5 inches in diameter, the stroke being 11 inches. The three cranks are set at 120 degrees. The H.P. cylinder is between the two L.P. cylinders, and is fitted with a piston valve. Flat valves are fitted on the L.P. cylinders. The

air pump is worked by levers from the forward engine. The feed pumps are worked at a reduced speed by worm gearing on the forward end of the shaft.

There is one Blechynden water tube boiler. The propeller is of bronze, 4 feet 10 inches in diameter, and has a pitch of 5.25 feet.

The dynamo is run by a Parson's steam turbine.

Anita.—Some particulars of this yacht, built at Skinner's shipyard, in Baltimore, were given on page 213 of the February number.

The length over all is 181 feet; length on the water line, 158 feet; beam, 22 feet; draught, 9.5 feet. She is composite built, the frames being of steel and the sides of hard pine. There are four water tight bulkheads. There is a deck house, 85 feet long forward, and 15 feet aft of this is another deck house, 25 feet long, used as a smoking room. The forward deck house contains the dining room, officers' mess room, pantry, galley and machinery hatch. The vessel is schooner rigged, with a square sail on the foremast. Below the main deck and forward of the steel fire room bulkhead are the forecastle, with bunks for a crew of twelve men, officers' rooms, and two state rooms for the owner, finished in mahogany. Aft of the engine bulkhead are two guests' rooms, occupying the width of the vessel, the main saloon, four smaller guests' rooms, and storerooms.

The stroke of the engines, which was incorrectly given as 28 inches, should be 20 inches. The propeller is four bladed and of manganese bronze.

Four boats, two of them naphtha launches, will be carried.

Wachusett.—This steam yacht, 95 feet in length, is building by the Gas Engine and Power Co., Morris Heights, New York, for Mr. F. T. Holden, of Yonkers, N. Y. The triple-expansion engine has been built by John W. Sullivan, New York, and is expected to develop 250 I.H.P. The boiler will be of the West patent water tube type.

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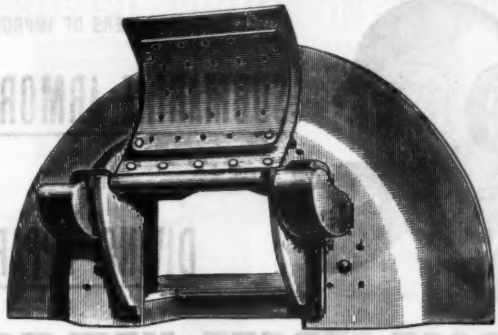

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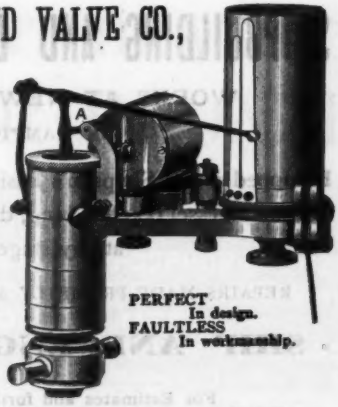

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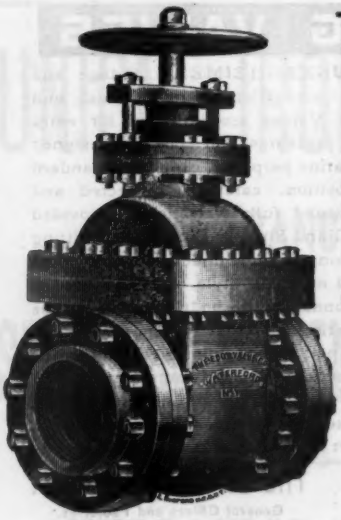

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